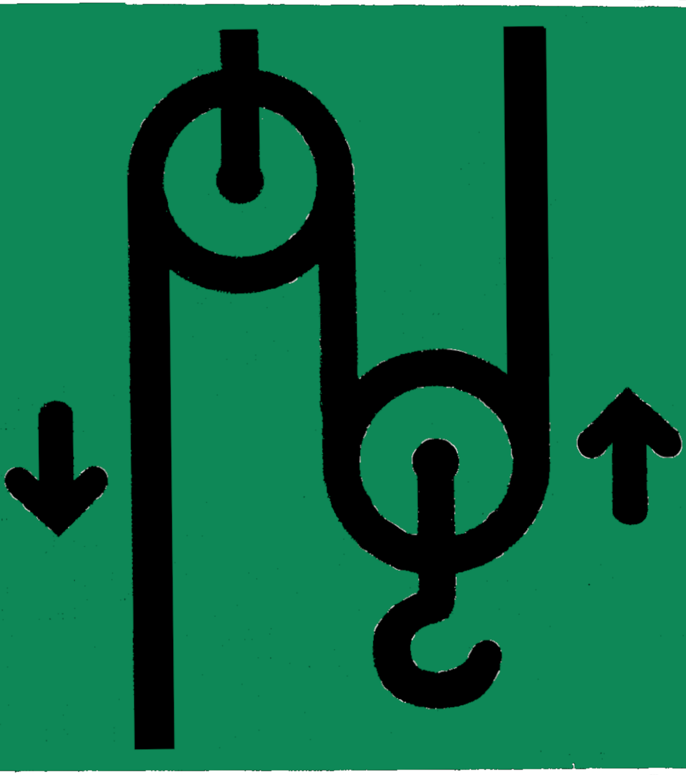
Ya. OBERMAN

Materials Handling



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INTRODUCTION

Development of metallurgy and growth of production of cold-rolled sheet metal, shaped and precise rolled products involve a considerable increase in the amount of raw materials and semi-finished products to be moved and processed. To produce only 1 tonne of finished rolled metal, it is necessary to haul about 40 tonnes of various materials. In the course of production materials are moved and transferred by means of hoisting and conveying machines provided with materials handling attachments and slings. A number of hoisting and conveying machines and mechanisms are an integral part of the production equipment (casting cranes, pit furnace and bridge cranes of rolling-mill shops, etc.).

Such peculiarities of metallurgical practice make it necessary for every workman to acquire a skill of a professional slinger in servicing hoisting and conveying machines and mechanisms. Efficient operation of the production equipment greatly depends on this skill and on the perfection of materials handling attachments.

The technical progress in industry is largely decided by the use of the automatic materials handling equipment with a remote control of pickup and release of the load. However, this does not diminish the importance of slinging operations which are still considerable in modern metallurgical practice.

An increase of the labour productivity and improvement of slinger's skill, quick and correct selection of slings, use of efficient methods of slinging acquire ever growing significance since they are connected not only with high productivity, long service life and reliable functioning of the equipment but also with safety in carrying out hoisting and conveying operations. Study of accidents shows that they primarily occur due to incompetent fulfilment of slinging operations in hoisting and conveying the materials or violation of the safety rules.

The present textbook is intended for training skilled workers in vocational schools for metallurgical industry who service a great number of the process stages of metal production from mines to piling of finished products.

Chapter I

Slinging Work, Duties and Responsibilities of a Slinger

1.1. Qualification Description of Slinging Work

Slinging is a set of operations and skills connected with servicing of hoisting and conveying machines and mechanisms. It includes attachment of slings to and tying of loads for their lifting, moving and stacking; keeping watch on the load being hoisted, moved and stacked; detachment of slings from the load after erection or stacking; stacking and stowing of materials; sending signals to a crane operator or a driver of the load-lifting mechanism; selection of necessary slings according to the weight and size of the load to be moved; determination of fitness of slings for work, etc. A workman engaged in this work is called a *slinger*.

Earlier, the above-listed operations were referred to as "rigging" but as load-lifting machines and mechanisms, as well as load handling attachments developed it became necessary to distinguish between the terms "slinging" and "rigging". At present "rigging" means operations of load moving in vertical and horizontal directions with the help of winches, hoists, jacks, trestles, chutes; erection of flooring, stanchions, temporary footways and arrangements; installation, mounting and dismounting of blocks, hoists, anchors, masts and lifting tackles; splicing of metal cables and ropes; reeving of ropes, and the like. "Slinging" means a plurality of ways of tying about and hooking of loads for their hoisting and moving by lifting appliances. Slinging is carried out by means of detachable hoisting devices applied to a crane hook (slings, load beams, grapples, buckets, etc.).

In this country slingers are qualified from the 2nd to the 6th skill categories depending on their capability to fulfil the work of different difficulty.

Qualification description of slinging work is as follows:

	Skill category
Slinging and tying of loads for hoisting, moving and stacking:	
(a) simple articles and the like loads weighing	
up to 5000 kg	2
from 5000 to 25 000 kg	3
more than 25 000 kg	4
(b) articles, components and assemblies of medium complexity including their placing on a bed frame, trestle with the help of mounting mechanisms and arrangements and other similar loads weighing	
up to 5000 kg	3
from 5000 to 25 000 kg	4
more than 25 000 kg	5
(c) complex articles, components and assemblies which require great care; production equipment and its structures, articles and assemblies; machines and mechanisms right in rig and section assembly and disassembly of machines, apparatus, structures of prefabricated parts of buildings and the like loads weighing:	
up to 5000 kg	4
from 5000 to 50 000 kg	5
more than 50 000 kg	6
(d) timber materials:	
— simple articles:	
to 3 m long	2
from 3 to 6 m long	3
longer than 6 m	4
— materials of medium complexity:	
to 3 m long	3
from 3 to 6 m long	4
longer than 6 m	5
— complex articles longer than 6 m	6
Detachment of slings from the mounted and stacked loads	2
Determination of sling fitness for haulage of materials	2
Selection of slings for materials moving in accordance with:	
weight and size	2
weight and kind (type)	4
Selection of methods for quick and safe slinging and movement of materials under various conditions	3
Splicing and connection of slings using different knots	3
Splicing of sling ends	4
Sending signals to a crane operator and keeping watch on the load during hoisting, moving and stacking	2

Description of a slinger's skills is the following:

	Skill category
Visual assessment of:	
weight of the load being moved	2
weight and center of gravity of the load being moved	3
Rules of slinging, hoisting and haulage of	
small-size simple loads	2
heavy-weight simple loads	3
light-weight loads of medium complexity	3
heavy-weight loads	4
critical loads	6
very heavy loads	6
Rules of assessing the most suitable places for slinging	3
Rules of choosing the methods of slinging of:	
standard loads	2
heavy loads	4
critical and very heavy loads	6
Methods of materials protection against damage and bending during lifting and movement of:	
heavy-weight loads	4
very heavy loads	5
Construction of hoisting and hauling devices	4
Construction of attachments used in lifting and haulage of loads in order to prevent them from damage and bending	5
The same for critical loads	6
Purpose and rules of application of slings, cables, chains, ropes, etc	2
Ultimate loads applied to slings and lifting capacity of a crane	2
Permissible loads	2
Lifting capacity of slings	3
Rules of assessing the length and diameter of slings for load movement	2
Methods of slings splicing and connection by knots	3
Rules and methods of slings splicing and loops making	4
Methods and periods of:	
employment of slings	3
testing of hoisting and hauling devices	3
Operation principles of hoisting and hauling devices	3
Rules and periods of employment of slings and determination of their lifting capacity	4
Methods and periods of testing and examination of slings	5
Signals used for transmitting commands from a slinger to a crane operator (driver)	2

1.2. Main Duties and Responsibilities of a Slinger. Slinger's Permit to Work

A slinger is allowed to work independently if he is older than 18 years of age, underwent a course of theoretical and practical training according to a special programme, acquired experience working as an assistant slinger, passed an examination to the plant's commission and was awarded a special certificate. In his work the slinger follows the Regulations which describe his rights, duties and the procedure for safe work with due allowance for the type of lifting and conveying equipment and provisions prescribed by the Rules of Construction and Safe Operation of Lifting Cranes. The Regulations are to be approved by the plant's authorities and given to the slinger before he is granted a permit to carry out independent work.

In solving technical problems the slinger is subordinated only to a specialist responsible for sound condition and safe operation of the crane serviced. Before starting the work the slinger must be given a list of loads which he is to handle most frequently wherein the weight and slinging charts are indicated if they are not posted at the construction site. He also must check the condition of the construction site, slings and other lifting appliances required for his work and the condition of packages, hooks and hook casings. After he has found that all the hoisting and hauling devices at the construction site are fit for service, the slinger is to be briefed about the rules of moving the loads at the area he is to attend and about the dimensions of storage places. He must remember that he is responsible for any accidents and damage which occur as a result of his wrong signalling to the crane operator or of improper slinging of the loads to be moved.

The slinger and crane operator commonly service the lifting crane, take their decisions independently and are personally responsible for their sectors; the crane operator is responsible for operating the crane, the slinger is responsible for slinging the load, however, any instructions given by the crane operator to the slinger are obligatory for fulfilment.

Slingers are trained in Technical Schools and at Plant's training centres including an obligatory practical course of training at the plant. Before the slinger is given a permit for independent work, he is to pass an examination to the examination board. Those who successfully passed the examination are awarded special certificates which are signed by the chairman of the examination board.

The slinger is allowed to service hoisting equipment by a special order issued at the enterprise.

Periodic qualification check of slingers' knowledge is carried out: annually if the slinger works continuously at one place; at the request of the authorities responsible for safe operation of hoisting machines if the slinger's actions raise any doubts in his qualification; if the enterprise receives detachable hoisting and hauling devices of a new type or slinging charts are changed; if the type of the load changes and new methods of slinging are to be used for its lifting and movement; if the slinger shifts to a new place of work; if the slinger has a break in his work for more than 6 months.

If there are changes in slinging charts, nature of the loads, use of hoisting and hauling devices of a new type, the slingers must undergo a course of training before certification during which they are taught safe methods of work, and the Regulations must be supplemented with necessary details.

Review Questions

1. What operations does slinging include?
2. What is the difference in the work of the slingers of the second and third skill categories?
3. What are the main responsibilities of a slinger?
4. What is the procedure for primary and periodic certification of slingers?

Chapter II

Loads and Packages in Metallurgical Practice

2.1. Loads in Metallurgical Practice

Raw materials, semi-finished items, finished products and equipment subject to hoisting and hauling are called *loads*. Modern metal production of a complete cycle includes the following: coal and ore mines; ore-dressing works wherein ore is crushed and concentrated and enriched concentrates are agglomerated; by-product coke plants with workshops for preparation and carbonization of coals and for recovery of chemical products; power shops for generation of oxygen, compressed air (blast) and purification of gases; blast-furnace shops for smelting iron and ferroalloys; steel-making shops (converter, open-hearth, electric furnace shops) for manufacture of steel; rolling-mill shops; charge preparing bays; foundries; a number of auxiliary productions; shops of finished products; stores of charge and auxiliary materials. Conveyed through all these production areas are ore, fuel, fluxes, charge, fettlings, ferroalloys, gaseous materials, liquids, powders, molten metal, rolled products, cast shapes, etc.

Depending on the kind, method of storage and slinging, materials are divided into several groups:

1. *Bulk materials* (ore, coal, sand, etc.) are transferred from the place of mining to the place of processing and are stored without packing (in bulk). Therefore, these materials are often referred to as *bulk loads.* This group of materials is divided into subgroups.

The first subgroup includes ore and charge materials which are delivered to the plant, as a rule, in dump cars and are unloaded into pits. At metal works ore and some charge materials are averaged and then reloaded into pans, bunkers, boxes and other containers.

The second subgroup comprises burnt dolomite, magnesite, lime, etc. They are usually transported to the works in hoppers, roofed gondolla cars and are unloaded through bottom hatches which are opened by means of special platforms moved by a crane along the train. These materials are stored in special bins. To reload materials of these two subgroups clampshell or clampshell-magnet cranes are used.

Ferroalloys constitute a special subgroup. They can be delivered in bulk but primarily they are transported in packages since they are expensive.

2. *Liquid and semi-liquid materials* are conveyed in special containers (tanks, ladles, mixers, barrels, etc). These materials are divided into the following subgroups:

(a) liquid materials transported in tanks, barrels, etc. (they include oil products and other similar fluids);

(b) hazardous materials delivered in special containers or in vessels (acids, alkalis, liquefied gases, etc.);

(c) molten metals conveyed in special ladles and mixers. A transfer of this subgroup of materials from a vessel to a vessel is accomplished by means of special casting cranes by tilting or through special discharge holes.

3. *Unit and packaged materials* are those of regular shape, which are stacked and stored in piles. This group of materials is divided into the following subgroups: metals and metal specialties, packaged materials, and unit materials (kept in piles or out of piles, long-cut, timber).

Metals and ferrous metal specialties are packed into bundles and piles, the same with large-diameter tubes, non-ferrous metal specialties, etc.

Packaged materials carried in boxes, barrels, drums, etc. are reloaded, as a rule, by means of highly efficient detachable hoisting and hauling devices and automatic slings.

Unit materials (kept in piles) are carried unpacked. They have a regular shape. Such materials can be stacked in piles and moved by slings or by special attachments which make it possible to mechanize materials handling.

Unit materials (not kept in piles) comprise metal structures, engines, cast shapes, etc. which cannot be arranged in regular lines. This subgroup is the most diverse and numerous in its shape and weight therefore there are no standard methods of their slinging.

4. *Long-cut materials* (those longer than 8 m) comprise rolled metal, tubes, etc. For their handling use is made of general-purpose slings and below-the-hook attachments provided with special grapples.

5. *Timber materials*—logs, lumber, etc. Used for their handling are general-purpose slings and specialized below-the-hook attachments.

As to weight, materials fall into the following categories:

(a) light-weight materials, weighing up to 250 kg;

(b) heavy-weight materials, weighing from 250 kg to 50 tonnes;

(c) very heavy materials, weighing more than 50 tonnes (as a rule these are unit materials not to be kept in piles, and ladles with molten metal and slag);

(d) dead materials which comprise materials of unknown weight, that is materials attached to the foundation by means of anchor bolts, dug into the ground, frozen to the ground, pressed by other materials, and the like.

Dead materials are strictly prohibited to be hoisted by lifting cranes.

Depending on the shape and size materials may be within or out of loading gauge.

Materials within loading gauge are those whose dimensions do not exceed the loading gauge of the railroad rolling stock. For automobile and other kinds of transport they should not exceed the norms prescribed for movement on streets and roads.

Materials out of loading gauge are those whose dimensions are out of the prescribed norms. The maximum dimensions are limited by the smallest clearance at which the transportation is still possible.

Materials received and dispatched by works are accompanied with certificates and load marks. Load marks comprise separately attached tags or inscriptions and symbols applied to the material or to its package. A load mark must contain information about the material weight: gross weight including the package weight; net weight, the weight without package; about precautions; about the places for slinging, etc. Some information is usually depicted by symbols which facilitate the assessment of the material kind and its properties. Special markings are prescribed for hazardous loads.

Review Questions

1. Give the definition of a load.
2. Into what groups are materials divided?
3. What materials belong to dead ones?

2.2. Packages in Metallurgical Practice

Packages comprise various vessels and shells in which the materials are conveyed. The purpose of the package is to make material convenient for movement and insure conditions for its qualitative and quantitative safety.

A considerable portion of materials at works is carried in production packages. Charge materials are carried in charging pans, scoops, buckets and movable bunkers. Molten metal and slag are conveyed in ladles and mixers. Finished rolled metal is collected in stacks. A *stack* is made up of small units on pallets or without them suitable for mechanical handling. It insures safety during transportation and storage. Packages may be rigid, semi-rigid and soft.

Soft packages which are cheap and light-weight are used for bulk materials of a small volume weight. Soft packages include bags, nets, sacks, bales, etc.

Semi-rigid packages are mainly used to carry bulk materials of a high volume weight such as iron scrap, charge materials, etc. Semi-rigid packages comprise metal baskets, chain suspended buckets, grids, etc.

Rigid packages are relatively expensive and labour-consuming in production. They are used always when it is necessary to prevent the material from deformation and damage under the influence of external forces. Rigid packages include boxes, barrels, pans, scoops, baskets, flasks and the like items which are capable of taking up loads developed by external forces. For long and durable transportation use is often made of containers. These are re-usable rigid packages of increased capacity which make it possible to mechanize materials handling and to considerably reduce labour consumption.

Before being used in the production cycle, packaged materials are usually kept *in piles.*

A *pile* is an arrangement of articles in rows stowed tier upon tier. A *row* is some pieces of a material arranged lengthwise. The row width is limited by the size of a material piece. A *stack* is a regular vertical arrangement of material units in which each upper piece coincides with the lower one. A *tier* is a horizontal layer of the pile.

Rigid packages are most widely used in metallurgical practice alongside with stacks, rolls, etc. Rolled sheets in bundles are tied with a metal tape thus forming a stack which rests on transverse or longitudinal wooden bars (slides) attached to its base. Merchant shapes more than 3 meters long are arranged in bundles and tied with wire or metal tape. Free-cutting, spring and rod steel is arranged in bundles up to 80 kg in weight. Press-shaped aluminium and aluminium alloys are packed in bundles up to 300 kg in weight.

It is prohibited to lift bundles of metal by binding belts which are not intended for the purpose.

Tubes up to 720 mm in diameter are packed in bundles and long-cut articles of rolled steel (channels, I-beams, rails, etc.) are conveyed without any packages. Wire and steel ropes up to 30 mm in diameter or up to 700 kg in weight are moved in bundles or coils. Ropes more than 30 mm in diameter or more than 700 kg in weight are wound about drums (wooden or metal). Steel tape is coiled into rolls.

Iron pigs and scrap are transported between the shops in boxes, buckets, and pans.

Pigs of non-ferrous metals are stowed in stacks. For this purpose use is made of pigs having side bosses formed as a result of difference in the pattern draft in the middle and end portions and the projections at the base. While arranging pigs into stacks they are mutually locked. Stacks are placed on pallets or on wooden bars.

Metalware, some kinds of non-ferrous metals and ferroalloys, electric equipment and a number of other articles are packed into boxes. Their gross weight is up to 50 kg depending on the kind of material.

Bulky and heavy parts and assemblies of the equipment are packed into wooden boxes which are provided with strong slides if their weight is more than 500 kg. They have pillars and cross members inside which are capable of supporting the material weight and insure its safety. The items and the box are fastened to the slides by bolts.

The larger portion of materials is conveyed in containers and metal packages. This kind of packages is standard. Standardized metal packages are manufactured as boxes without supports, with collapsible wall, of a frame and pillar type. All kinds of packages are designed for a certain load. When filled with materials their gross weight should not be more than it is permitted. The packages must withstand dynamic loads arising during transportation while lifting and lowering the materials.

Their bottoms and supports are designed to accept a force caused by 2g acceleration (g being a free fall acceleration in m/s^2), while the pillars and walls are to withstand a force caused by $1.1g$ (except the packages having net walls). The packages must be strong enough to insure safety during movement by materials handling facilities. While calculating the package strength, the load is to be taken equal to $1.25\ Qg \cdot (k - 1)$, where Q is the gross weight, kg; k is the number of tiers in storage. The package cover must accept a load of 1 kN evenly distributed over an area of 100 × 100 mm. The packages outfitted with facilities for gripping whose location permits the gripping from any side, must be calculated for a load of $2Qg$ assuming that it is evenly distributed among all gripping elements. The flatness error of the bearing surface of the package must not exceed 2 mm for an area of 600 × 400 mm (length × width); 2.5 mm for 800 × 600 mm; 3 mm for 1200 × 800 mm; and 4 mm for 1600 × 1200 mm.

To increase stability in piling up, packages are provided with fixing facilities. A free play of packages in these facilities must insure their piling-up by means of machines and mechanisms. To prevent the forks of materials handling machines from lateral sliding, packages are provided with various friction appliances or stops. Applied to the external side of a package are symbols of the gross weight (in tonnes) and the package weight (determined by weighing). Packages are manufactured according to the standards, flowsheets or drawings approved by corresponding authorities and information about them is entered into a record wherein the name, load-carrying capacity, and the results of checking the quality of joining are indicated.

Packages whose gross weight is more than 50 kg, are subject to technical inspection before putting into operation, every 6 months, and after repair. Packages which are liable to testing by the State Examination Agency (vessels and tanks, flasks for storage and transportation of compressed and liquefied gases, etc.) are put through inspection before putting into operation, every month and after repair. During inspection it is necessary to make sure that there are no cracks in the places of securing the gripping attachments, that clamping and locking facilities are serviceable, and the marking is readable. The results of technical inspection are entered into a special log. The date of inspection is applied to the package.

Review Questions

1. What kinds of packages do you know?
2. Is it possible to lift stacks and bundles by their tying belts?
3. What is the procedure of package inspection?

2.3. Construction of General-purpose Packages

Bags. Bags are used to deliver loose materials: asbestos, cement, graphite, gypsum, sulphur and the like. Industry manufactures cloth, paper and polyethylene bags. Cloth bags are made of flax, jute and other cloth, but such bags are of a limited use at metal works.

Bitumen-impregnated bags are used for packing hygroscopic materials. They are stitched or glued of several layers of paper. Depending on the purpose such bags are made of three kinds: bitumen-impregnated bags with two or three layers of bitumen-impregnated paper and several bitumen-free paper layers; double bags with one or two-three layers of doubled paper and several layers of nonimpregnated paper; watertight bags with an outer layer of moisture-resistant paper and the inner layers of bitumen-impregnated or doubled paper. The total number of bag layers is from three to six.

Polyethylene bags are used for packing, transportation and storage of loose chemicals up to 50 kg in weight. The bags also find use for transporting various loose materials provided they insure preservation of such products in handling and storing.

Barrels. The nomenclature of materials transported in barrels is diverse. In metal production barrels are used to hold oil products, acids, water glass, etc. Usually, they are made of steel sheets and sometimes of aluminium sheets. The aluminium barrels are employed to transport liquid, viscous and loose materials which do not react with aluminium.

Drums. Drums find use for storage and transportation of loose, paste-form and lump materials. Welded and rolled steel drums are intended for packing ferroalloys, silicon, manganese, and chrome. The gross weight of a welded drum is not more than 500 kg and that of a rolled drum, 250 kg. Thick-walled steel drums of 0.1 m^3 capacity find application for packing, storage and transportation of loose and paste-form products of chemical production. Drums are usually made of steel sheets and sometimes of wood. They have a central hole with metal planks or bushings at the edges which is provided for fastening slings or special gripping devices. Manual movement and handling of drums is not allowed.

Boxes. Depending on the weight, chemical, physical and biological properties of materials use is made of board, plywood, cardboard, metal boxes. Wooden boxes are divided into solid boxes and crates.

Solid boxes differ in the construction of the end wall. For example, those weighing up to 30 kg have the end walls made of one piece or composite of some boards joined by nails, those up to 110 kg have the end walls reinforced with external or internal planks arranged vertically or horizontally, and these up to 200 kg have the end walls made up by four external posts which form a frame.

Crates are reinforced with braces or angle members. In order to increase the strength and rigidity of large crates, additional belts and planks are used. In some cases the crates are slide-mounted. Now metal reusable boxes come in use which make it possible to reduce expenses for packages and to mechanize materials handling operations.

Stacks. Stacks are employed to convey the products of metal works: steel shapes and steel sheets, metal in pigs, etc. Rolled articles, wire coils and drums are arranged in stacks. To form stacks, use is made of wooden, metal and synthetic-material pallets, tape slings of different designs, pillar and open box-type pallets. A pallet (a multi-purpose platform) comprises three bars arranged so that the forks of lift trucks can easily pass therebetween. At both sides the said bars mount 40 or 50-mm boards whose ends go behind the bars and are used to catch the pallet by slings or by a special business-end tool. The pallets may be single-layer (the boards are secured only to the upper part of the bars) or double-layer (the boards are fastened both to the upper and the lower surfaces of the bars). A pallet may support from 900 to 3000 kg of load. The weight of a wooden pallet is 70-80 kg. Structurally, a pallet can be gripped from two sides and from four sides. The pallet dimensions are standardized: a 800 × 1200 × 150 mm pallet is designed to carry 1000 kg; a 1200 × 1600 × 180 mm pallet and a 1200 × 1800 × 220 mm pallet are designed for a 2000-kg load. Alongside with wooden pallets use is made of metal pallets in a number of cases. Their main disadvantage is great own weight (about 150 kg).

Review Questions

1. What general-purpose packages are used at metal works?
2. How is the drum slung?
3. How is the pallet slung?

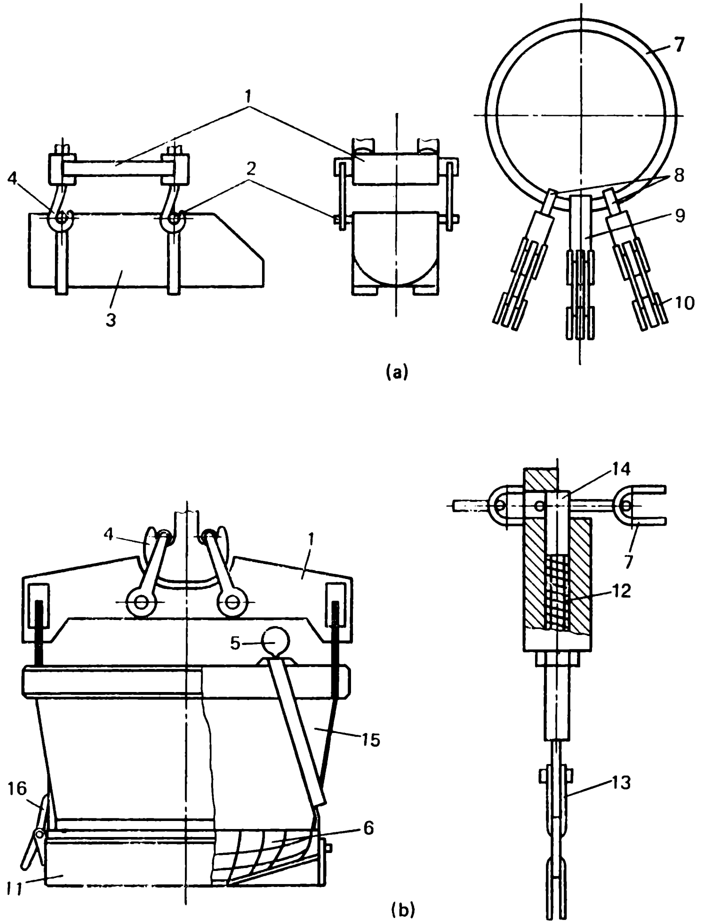
2.4. Charging Vessels Used in Metal Making Shops

To smelt metal, materials are delivered from places of storage and charge preparation to the charging bay and are loaded into the furnace. Converters are charged with the use of a scoop. A scoop is a steel bucket welded of steel sheets without an end wall, and the bottom is trough-shaped to facilitate the scrap release. The scoop width is equal to the size of the converter mouth. To add to rigidity, two box-section belts are welded throughout the scoop length. The distance between the belts must be equal to 2/3 of the scoop length. Secured to the belts are trunnions for gripping the scoop with load beam hooks (Fig. 1). The capacity of the scoop for charging the scrap into a converter must be close to the weight of the charge loaded into the converter. The scoop belts are made flat from beneath. They have two thrust supports to rest on the floor charging platforms. Thrust supports enable the scoop to be caught by forklifts and if using the slings they prevent the scoop from sliding away in conveying.

Electric furnaces are charged with the aid of buckets. The charging bucket is a round weldment with a sector bottom of a grab type and rigid scoops which get open by means of a leverage. The charging bucket with a flexible sector bottom is usually placed onto a pallet. The bottom comprises a set of leaf chains *10* combined into sectors terminating in rings in the lower portion. To lock the bottom, the bucket is lowered onto a pallet. As this takes place, flexible sectors slide over the slope of the pallet and converge in the center. Thereafter an end ring is passed through the rings. One end of the end ring is rigidly secured to the sector with a lock, while the second end, which has passed through all the rings of the sectors, is fastened in the lack by a pin which is kept from falling out by a spring. The pin is connected to the ring secured to the bucket body by means of a chain. The bucket with a closed bottom is attached to the pallet with locks, placed onto a transfer car and is delivered to the charging bay. The bucket is hoisted and conveyed with the help of a load beam.

To load open-hearth furnaces, charging boxes are used. It is a cast steel container, one end wall of which has a pocket serving as a lock and as a stop and receiving an arm head of the charging machine. The charging box bottom is provided with 10-mm holes to drain water and oil dripping from the charge materials. Depending on the structure of the furnaces used the charging box capacity varies from 0.75 to 3.3 m^3. To convey charging boxes from the stockyard to the charging bay of the open-hearth plant, two-axle cars are used. According to the charging boxes to be transported the load-carrying capacity of the cars is 30, 40, 45 tonnes. A charging box is captured by the charging machine arm in the following way. The machine operator dips the arm head into the charging box pocket and imparts motion to the block through the link. The block comes out of the head slot, enters the slot in the front wall of the charging box pocket and rigidly connects the charging box with the arm head. In this position the charging machine arm hoists the charging box with the charge and introduces it into the furnace through the charging port.

Charging boxes are also used to fill cushion and repair the furnace. The cushion is filled by means of a charging machine using special charging boxes. The boxes are loaded with magnesite powder and are covered with a special screen having a great number of small



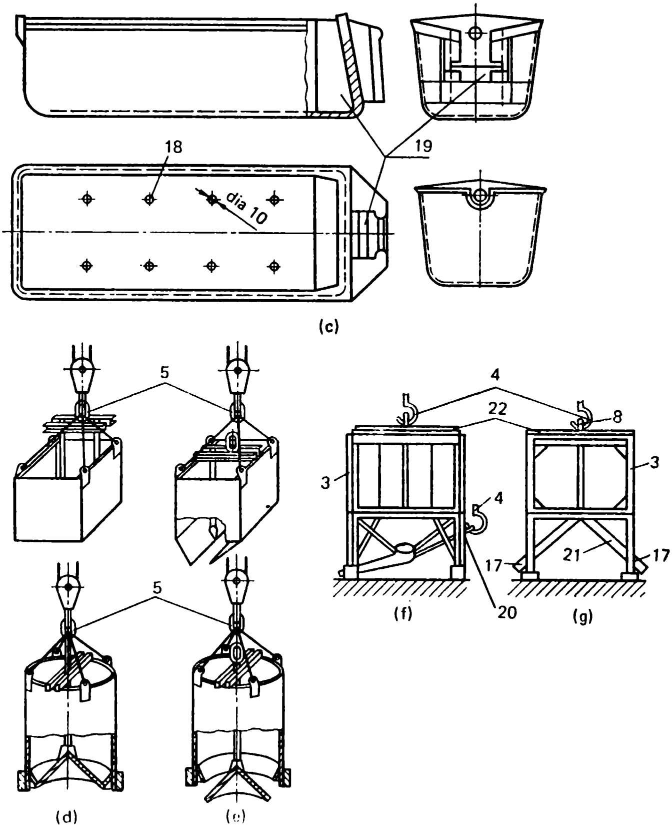
(a)

(b)

Fig. 1. Charging vessels used
a—scoop; *b*—bucket; *c*—charging pan; *d*—containers for conveying
the same in unloading position; *f*—bunker for conveying bulk ma-
bunker for bulk materials; *1*—load beam; *2*—trunnion; *3*—body;
the chain sector; *10*—laminated chains; *11*—bottom plate; *12*—
coupling the body with bottom plate; *17*—material dispensing lip;
20—mechanism for opening and closing the

holes. To fill the hearth right at the back wall, it is a good practice to make use of a charging box made 1 m longer.

To raise the productivity of steel melting furnaces and to make the best use of the power of the charging machine and the load-carrying capacity of the cars, to reduce the length of the trains and to speed



(c) (d) (e) (f) (g)

in metallurgical practice:
and mechanized unloading of ferroalloys in travelling position; *e*—
terials provided with a funnel-type discharge; *g*—double-lipped
4—hook; *5*—ring; *6*—bottom; *7*—end ring; *8*—ring; *9*—lock of
spring; *13*—pin chain; *14*—pin; *15*—bucket body; *16*—lock for
18—holes for draining water and oil; *19*—pocket for charging ram;
chute; *21*—hand-operated lower shutter; *22*—net

up the process of charging, the volume of a charging box for particular conditions must be as large as possible.

To charge into the furnace rejected ingots, moulds, rolls, packs and other large-size scrap which fit the largest size of the charging port and the maximum load-carrying capacity of the charging machine but are out of size of the charging box, use is made of the trays, i.e. charging boxes with low walls and without the front wall.

Charging boxes and self-discharging containers are employed to feed ferroalloys into the furnace. The self-discharging containers comprise a steel housing of a square or circular cross-section and a dumping bottom. Welded to the housing are four ears for sling fastening. The bottom has either two flaps or a cone connected by a link to a loop. When the hook of the hoisting mechanism has caught the link and goes up the flaps or the cone close the container bottom. As soon as the link is released the container bottom gets open in response to the load weight. The upper part of the link mounts the limiters which prevent it from moving downward.

Fettling materials (magnesite powder and burnt dolomite) are stored in low-wall boxes located on a platform in front of the furnace. The boxes are made from steel plates by welding and are reinforced by a belt to which the trunnions for slings are welded. Fettling materials are often conveyed in bunkers. A double-lipped bunker is used when the shop is lacking machines for filling up the sills.

The bunker for moving and storing ferroalloys is a container made of steel plates and supported by a high frame under which the material dispensing lips and chutes are arranged. To discharge the material, the chute has an open-close mechanism which can be actuated by a crane or manually. From the top the bunker is closed with a net. The stiffening ribs mount a ring to catch the crane hook.

Review Questions

1. What charging vessels are used at metallurgical works?
2. What is the design of a charging bucket?
3. What is the design of a charging box?

2.5. Ladles, Mixers, Moulds

To move and teem molten metal use is made of the ladles of different design. •

Ladles for conveying pig iron from blast furnaces (Fig. 2) to the casting bay are made of steel plates. Welded to the ladle shell at both sides are steel cast plates *5*. Each plate has three trunnions and two claws *4*. The lower trunnions *6* support the ladle on the carriage, while the upper trunnions *7* are used to hook the ladle when removing it from the carriage by the crane. Attached (welded) to the lower portion of the ladle body are two lugs *9* with a roll to engage the crane hook or the tilting device during iron teeming. Most commonly employed in ferrous metallurgy are semi-covered pear-shaped ladles having a capacity of 80, 100 and 140 tonnes. From inside the ladles are lined with chamotte bricks. Ladles are mounted on carriages *2* of special iron carriers comprising two railroad-type bogies *3* which support frame *10* provided with automatic coupler *11*. To reduce the heat losses during hot-metal transportation and to prevent salamander formation in the ladle, the latter is outfitted with cover *1* which is bolted to the ladle and lined with fire bricks. The cover has two pouring lips *8*.

Slag cars are designed to transport the ladles carrying molten slag from the blast furnaces to the granulation plants or to the slag dump of the enterprise. The same ladles are intended to convey the slag of steel making

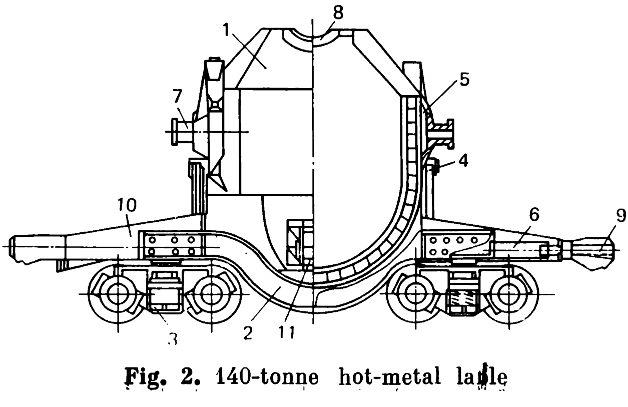


Fig. 2. 140-tonne hot-metal ladle

furnaces. Ladles for slag movement are usually made of cast iron or welded of steel plates. Depending on the furnace productivity use is made of slag ladles of 11 and 16.5 m^3 capacity. The 11-m^3 ladles are circular in cross section, while the 16.5-m^3 ladles are of elongated shape with an elliptical cross section. To facilitate the knocking-out of the slag remains, the ladle bottom is made spherical. Slag ladles are not lined.

Steel-teeming ladles are designed to receive steel from a steel-making plant, to convey it and subsequently pour into ingot moulds or moulds of a continuous casting machine. The ladles of a capacity from 130 to 480 tonnes employed in steel making shops are actually steel welded containers protected from inside with refractory lining and provided with arrangements for transportation and delivery of steel. The ladle capacity is selected with due allowance for the fact that in addition to metal the ladle must also hold a 150-250 mm layer of slag, which protects the metal against oxidizing and minimize heat losses during teeming.

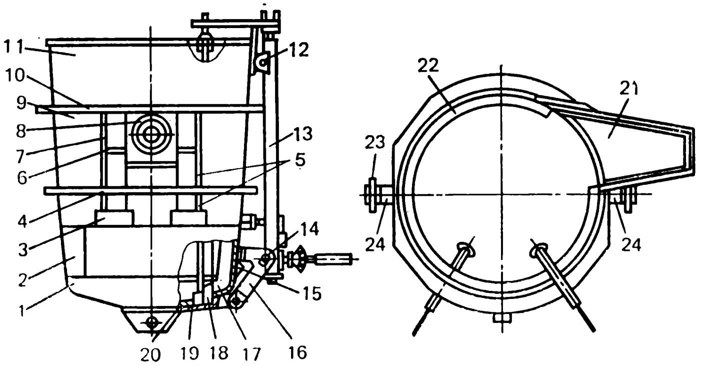


Fig. 3. Steel-teeming ladle

The main components of a steel-teeming ladle are a body, tilting device and two stoppers (Fig. 3). The ladle body comprises a casing, a trunnion belt, a bottom, and a slag chute. The casing is butt-welded of three shells: upper shell *11*, intermediate shell *9*, and lower shell *2*. In a longitudinal section it has a shape of a truncated cone, and in a cross section it is a circule. Welded in the upper portion of the casing are brackets *12* to mount stopper *13* and ring *22* to provide a required stiffness of the casing and prevent the lining from falling out during ladle tilting. The trunnion belt consists of annular stiffening ribs *10* and *4* (the upper and the lower ones), vertical stiffening ribs *5* and *7*, two trunnion plates *8*, and trunnions *24*. Forged trunnion plates are welded to the upper annular stiffening rib and to the casing, while to the lower stiffening rib they are connected through ribs *5*. Vertical ribs *7* are welded to ribs *10* and *4* and are connected to the trunnion plates by horizontal ribs *6*. Trunnions *24* designed for ladle catching by the casting crane beam hooks are press-fitted into the trunnion plates from the internal side of the casing. To prevent the ladle with metal from self-tilting, the trunnion axis is located above the ladle center of gravity. The trunnions per se are provided with safety washers *23* welded from outside so as to prevent the hooks from sliding off the trunnions. To fix the ladle on the stand or on the teeming ladle car, it is provided with brackets *3* which are welded to the lower stiffening annular rib of the trunnion plates. Bottom *1* of the ladle is made convex (it may be flat as well) and is lined with fire bricks. To discharge the metal from the ladle, the bottom lining is provided with two teeming sleeves *18*. To ensure free running of metal, the bottom lining is slightly sloped in the direction of the teeming sleeves which are closed with a plug *19*. The slag chute *21* is designed for draining the slag when the ladle is overfilled with metal. The tilting device is used for inclining the ladle to get rid of the slag and the metal remained after teeming. The ladle is tilted by engaging axle *14* of bail *16* with the small hook of the casting crane. In the initial position the bail is retained from falling down by catch *15* welded to the lower portion of the casing shell. While moving upward the bail rotates about the pivot connecting the bail to link *20* and disengages from the catch. In further movement the projection of link *20* thrusts against the ladle bottom and turns it about the trunnions.

Mixer is designed to equalize the chemical composition and temperature of the pig iron fed to the steel-making furnace. There are mixers of 150, 420, 600 tonne capacity.

A movable mixer (Fig. 4) consists of a cigar-shaped body *7* lined on the inside with fire bricks, support assemblies *6* and *10*, a rotation gear drive *5*, a running gear, and a driver's cab *4*. The mixer is provided with a mechanisms lubricating system and a system for measuring the molten metal temperature. The mixer body is welded of five shells: three central cylindrical shells and two end tapered shells. The trunnions are welded to the tapered shells. Provided in the cylindrical portion of the body are a filling opening *8* which has a replaceable lip for metal discharge welded to it and two additional holes *9* used when making, repairing and drying the lining. To jack the body for repair of the backing bearings, brackets *11* are welded below. The running gear of the mixer consists of two 8-axle composite balancing carriages, a braking system, and an automatic coupling. Each 8-axle carriage is made up of four double-axle railroad bogies *3* paired by means of pivotal joints with intermediate balance beams *2* and all together they are connected to the main balance beam *1* which mounts the assemblies supporting the mixer body.

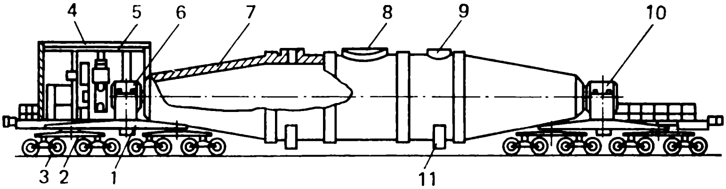


Fig. 4. Movable mixer

Moulds are cast permanent structures for casting steel ingots of required weight and shape subject to subsequent plastic working: rolling, forging, pressing. The moulds can be rectangular, square, round and polyhedral in cross section, the shape being conditioned by further treatment of ingots.

Rectangular moulds used to cast ingots for production of thick and medium sheets are called sheet moulds. Moulds used to cast ingots liable to subsequent processing on a slabbing mill to produce flat billets (slabs) are

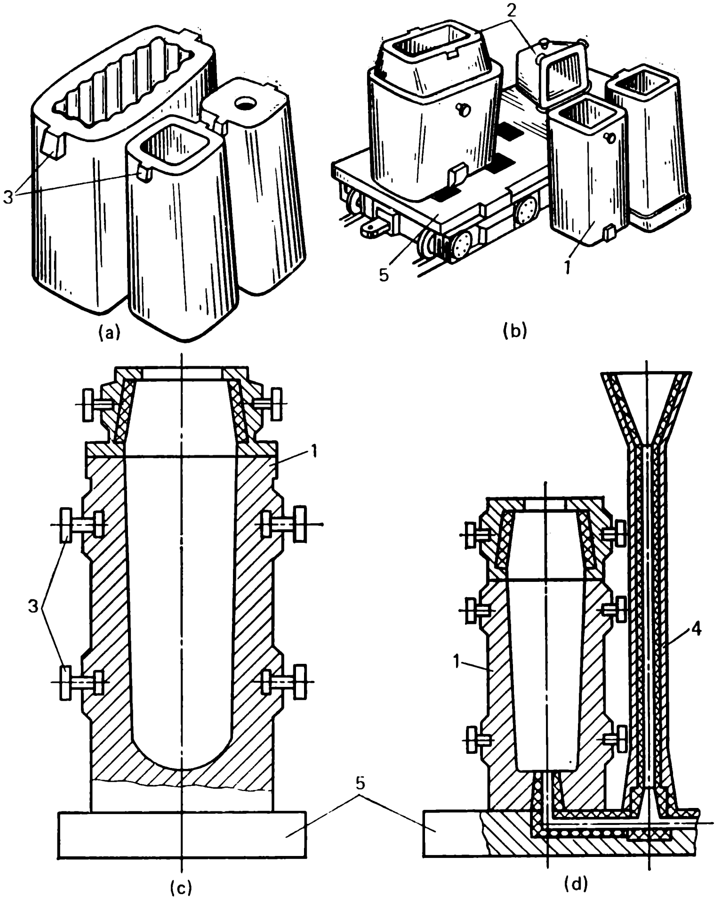


Fig. 5. Ingot moulds:
a—open-bottom mould; *b*—closed-bottom mould; *c*—top-poured mould assembly; *d*—bottom-poured mould assembly; *1*—ingot mould; *2*—top; *3*—trunnion; *4*—fountain; *5*—bottom plate

called slab moulds. The weight of ingots cast in moulds in lot production is 0.25-50 tonnes (Fig. 5). To facilitate withdrawal of ingots from moulds the latter are made tapered and accordingly are divided into big-end-up and big-end-down ones. Structurally, the moulds can be open-bottom and closed-bottom moulds. Open-bottom big-end-down moulds of a square and rectangular cross section are used for casting rimming, killed and semi-killed steels. The walls of these moulds are made flat or slightly convex to avoid ingot cracking during the starting period of solidification. For the same purpose the inner wall surface of the moulds for big square and slab ingots of rimming steel is made wavy. Open-bottom moulds are placed on individual cast iron base plates. Closed-bottom big-end-up moulds are used for casting killed and alloyed steels. Ingots intended for forging are cast in polyhedral moulds, often in octahedral moulds. Hollow ingots are produced with the use of open-bottom round moulds.

On the outside the moulds are provided with lugs, shackles or trunnions for catching the moulds with tongs of a stripping crane and holding them while the ingot is being withdrawn and for moving the ingots. In open-bottom moulds the lugs are made in the upper portion, while in closed-bottom moulds, in the upper and lower portions. The ratio of the wall thickness to the cross section of the mould is usually 20-25 and that of the mould weight to the ingot weight, 0.7-1.3. The bottom of the closed-bottom moulds has a hole which is closed with a steel or graphite plug during pouring. As a rule, moulds are made of cast iron.

Review Questions

1. What equipment is used to transport pig iron from the blast furnace to the casting bay?
2. What vessel is used to transport and hold pig iron before pouring into a steel-making furnace?
3. How is molten steel transported?

2.6. Assessment of Mass and Position of the Center of Gravity of Materials

The *mass* of the material is defined as a physical characteristic (scalar, undirected) of the body which is the measure of its inertial and gravitational properties. The body mass value does not depend on the free fall acceleration at the point of determination. At rest it is determined by weighing the body on lever scales. The weighing results indicate a value comparable with the mass of the scale weights expressed in mass units—gramme (g), kilogramme (kg), tonne (t).

Gravitational force is a vector (directed) value which defines the gravitational pull of the body to the Earth or to some other celestial body. The gravitational force value depends on the free fall acceleration at the point of determination. The gravitational force at a pole is greater as compared with that at the equator. As the body goes away from the Earth its gravitational force is decreasing. This value is measured by means of dynamometer under the conditions of relative rest of the body. Gravitational force like any other force is expressed in force units—newtons (N), kilonewtons (kN) and in other fractions or multiple magnitudes of these values.

A body weight is a force with which a body acts on the support (or suspension) due to gravitational pull to the Earth. The body weight is equal to the gravitational force provided that the support and the body are stationary with reference to the Earth. The weight unit as well as gravitational force unit in the International System of Units is newton (N).

A *lifting capacity* of a crane, lift truck, battery-powered truck is the maximum mass of material which the above vehicle can hoist, move or transport at a time.

Lifting capacity, as well as the mass, is a scalar value and is measured in mass units—gramme (g), kilogramme (kg), tonne (t).

Lifting force (similarly to the gravitational force) is a value characterizing the vehicle ability to hoist and move the material mass. The units of measurement of the lifting force are newton (N), kilonewton (kN) and other fractional and multiple magnitudes of a newton.

Before attaching the slings to the material to be moved a slinger should determine its mass. The mass of the items manufactured at the plant is indicated in the item drawings. The mass of the equipment, appliances, mechanisms is given in a tag attached to the frame or to the stand. If the material is packed its mass is inscribed on the packing. However, sometimes the mass of the material to be moved is to be estimated by the slinger by eye. Density of materials often used in metallurgical production is given below, kg/m^3:

Aluminium	2550-2700
Concrete	2200
Water	1000
Tungsten	19 300
Wood:	
birch	700
oak	800
pine	500
Soil, clay	1300-2500
Sandstone	2200-2500
Sand:	
dry	1400-1600
wet	1900-2000
Brickwork	1420-1700
Brass	8500
Ice	900
Copper	8900
Chalk	2400
Nickel	8900
Tin	7300
Paraffin wax	900
Lead	11 300
Steel:	
solid	7300
molten	7500
Zink	6900-7300
Pig iron:	
white	7650
malleable	7300
grey	7550
Coal	900
Coke	450
Nitrogen, liquid	790
Gasoline	700
Air, liquid	860
Kerosene	800
Oxygen, liquid	1140
Fuel oil	900

To determine the material mass the following formulae are used:

for simple loads:

$$Q = mV;$$

for complex loads:

$$Q = m\Sigma V_i$$

where Q is the load mass; m is the material density; V is the load volume; V_i is the volume of all component parts of the load.

The volume of regular geometric figures is disclosed in Table 1.

Example 1. Find the mass of the ingot whose dimensions are given in Fig. 6.

Let's divide the ingot into three truncated cones and find the volume of each cone. To this end, find the formula of a truncated cone volume in Table 1.

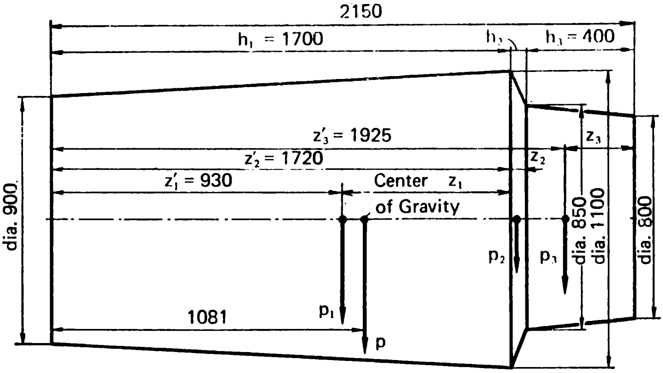


Fig. 6. Ingot dimensions

$$V = (3.14/3)\, h\, (R^2 + r^2 + Rr)$$

Then, find the volume of each element of the ingot

$$V_1 \simeq (3.14/3)\, 1.700\, [0.55^2 + 0.45^2 + 0.55 \cdot 0.45] \approx 1.34 \text{ m}^3;$$

$$V_2 \simeq (3.14/3)\, 0.05\, [0.55^2 + 0.42^2 + 0.55 \cdot 0.42] \simeq 0.04 \text{ m}^3;$$

$$V_3 \simeq (3.14/3)\, 0.4\, [0.42^2 + 0.4^2 + 0.42 \cdot 0.4] \approx 0.21 \text{ m}^3$$

Determine the total volume of the ingot: $V = V_1 + V_2 + V_3 = 1.34 + 0.04 + 0.21 = 1.59$ m³.

Table 1. Volume and Location of the Center of Gravity of Simple Configurations

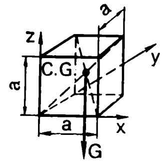


Fig. 1

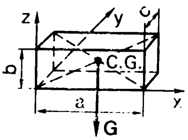


Fig. 2

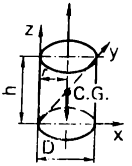


Fig. 3

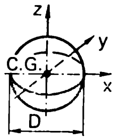


Fig. 4

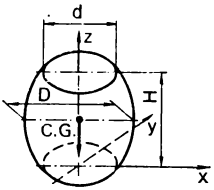


Fig. 5

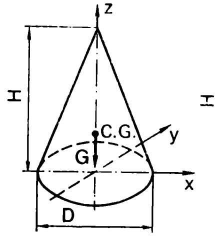


Fig. 6

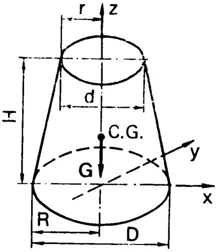


Fig. 7

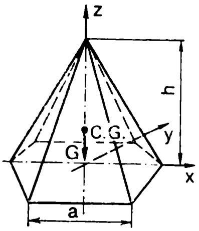


Fig. 8

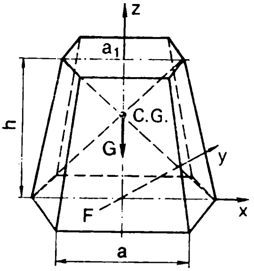


Fig. 9

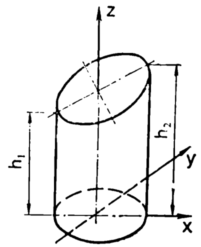


Fig. 10

Configuration	Presentation	Volume	Location of the center of gravity
Cube	Fig. 1	$V = a^3$	$x = a/2,\ y = a/2,\ z = a/2$ $x = y = z = a/2$
Right parallelepiped	Fig. 2	$V = abc$	$x = a/2,\ y = c/2,\ z = b/2$
Cylinder	Fig. 3	$V = 3.14 \times r^2 h$	$x = r,\ y = 0,\ z = h/2$

Table 1. *(continued)*

Configuration	Presentation	Volume	Location of the center of gravity
Sphere	Fig. 4	$V=3.14/D^3/6$	If the coordinate axes pass through the center of the sphere, then $x=y=z=0$ (the center of gravity coincides with the center of the sphere)
Rundlet	Fig. 5	$V=3.14/12H \times (2D^2+d^2)$	$x=y=0,\ z=H/2$
Cone	Fig. 6	$V=3.14/12D^2H$	$x=y=0,\ z=H/4$
Truncated cone	Fig. 7	$V=\left(\frac{3.14H}{3}\right) \times (R^2+r^2+Rr)$	$x=y=0$ $z=H/4\,[(R^2+3r^2+2Rr)/(R^2+r^2+Rr)]$
Pyramid	Fig. 8	$V=(Fh)/3$, where F is the area of the polygon base	$x=y=0,\ z=h/4$
Truncated pyramid	Fig. 9	$V=h\,[F+f+\sqrt{Ff}]/3$	$x=y=0,\ z=h/4\ [F+2\sqrt{Ff}+3f/F]$ $+\sqrt{Ff}+f$
Truncated cylinder	Fig. 10	$V=3.14R^2 \times (h_1+h_2)/2$	$x=y=0,\ z=(h_1+h_2)/2$

Assume the ingot density to be equal to 7.8 t/m^3, and find the ingot mass

$$Q = mV = 7.8 \cdot 1.59 \simeq 12.4 \text{ t}$$

While selecting the places of sling attachment to the load there is a need to locate the center of gravity of the load to be hoisted. If this is neglected in slinging there may occur an emergency case associated with overload of separate legs of the slings, lifting appliances; loss of stability and overturning of the object being hoisted. The position of the center of gravity of various geometric bodies is found according to coordinates $x_{c.g}$, $y_{c.g}$, $z_{c.g}$ which are determined by the formulae

$$x_{c.g} = \Sigma Q_i x_i / Q;\ y_{c.g} = \Sigma Q_i y_i / Q;\ z_{c.g} = \Sigma Q_i z_i / Q$$

where $x_{c.g}$, $y_{c.g}$, $z_{c.g}$ are the distances from the center of gravity of the body to the plane passing perpendicular to the axis considered through the origin of coordinates, m; x_i, y_i, z_i are the distances from the center of gravity of the body separate part considered to the same plane, m; Q is the total mass of the body, t; Q_i is the mass of the body separate part considered, t.

Coordinates of the center of gravity of regular geometric figures are given in Table 1.

Example 2. Find the position of the center of gravity of the steel ingot shown in Fig. 6.

Let's divide the ingot into three regular truncated cones. Using Table 1 we find the formulae determining the coordinates of the center of gravity for them. The plane of origin is assumed to be passing through the lower base of the ingot perpendicular to its axis. From the previous example it is known that separate parts of the ingot have the following mass $Q_1 = 10.45$; $Q_2 = 0.31$; $Q_3 = 1.64$ t, and the total mass is 12.4 t. Taking into account the fact that the ingot is symmetrical with reference to its axis we find the coordinate $z_{c.g}$ only. The coordinates $x_{c.g}$, $y_{c.g}$ will be located on the axis. The formula determining the coordinate $z_{c.g}$ of a truncated cone is

$$z_{c.g.} = h\left(\frac{R^3+2Rr+3r^2}{R^2+Rr+r^2}\right)/4$$

Knowing that $h_1 = 1.7$ m; $R_1 = 0.55$ m; $r_1 = 0.45$ m, we have

$$z_1 = \frac{1.7}{4}\left(\frac{0.55^2+2\cdot 0.55\cdot 0.45+3\cdot 0.45^2}{0.55^2+0.55\cdot 0.45+0.45^2}\right) = 0.77 \text{ m}$$

The distance z_1' to the plane of origin is found as $1.7 - z_1 = 1.7 - 0.77 = 0.930$ m.

Knowing that $h_2 = 0.05$ m; $R_2 = 0.55$ m; $r_2 = 0.425$ m, we have

$$z_2 = \frac{0.05}{4}\left(\frac{0.55^2+2\cdot 0.55\cdot 0.425+3\cdot 0.425^2}{0.55^2+0.55\cdot 0.425+0.425^2}\right) \simeq 0.021 \text{ m}$$

The distance z_2' to the plane of origin is found as $1.7 + z_2 = 1.7 + 0.02 = 1.72$ m.

Knowing that $h_3 = 0.4$ m; $R_3 = 0.425$ m; $r_3 = 0.40$ m, we have

$$z_3 = \frac{0.4}{4}\left(\frac{0.425^2+2\cdot 0.425\cdot 0.4+3\cdot 0.4^2}{0.425^2+0.425\cdot 0.4+0.4^2}\right) \simeq 0.176 \text{ m}$$

The distance z_3' to the plane of origin is $1.7 + 0.05 + 0.176 = 1.926$ m.

Determine the location of the center of gravity using the formula

$$z_{c.g} = (Q_1z_1' + Q_2z_2' + Q_3z_3')/Q$$

Substituting the corresponding values into the formula, we find the distance between the center of gravity and the origin of coordinates

$$z_{c.g} = (10.45\cdot 0.93 + 0.31\cdot 1.72 + 1.64\cdot 1.926)/12.4 = 1.081 \text{ m}$$

Having found the distance from the center of gravity to the assumed coordinate origin, it is transferred to the load to be hoisted and a mark is made with chalk or by any other method.

The slinging places must be located symmetrical with reference to the center of gravity so that the vertical line passing through the center of gravity is located between the places of sling attachment. The greater the distance between the slinging places, the more stable the position of the load, all other things being equal.

For packaged materials, the center of gravity is indicated on the package.

When the configuration of the item makes it difficult to calculate the center of gravity, the following practical technique can be used. Having found the item weight, an adequate sling is used to lift the item by one of its edges. Then the vertical lines are drawn on two planes of the hoisted item as a continuation of the sling legs. After that the item is lowered and lifted by the other edge. The vertical lines are drawn again through the same planes. The point of intersection of the vertical lines will show the position of the center of gravity of the item to be hoisted.

In the cases when it is difficult for the slinger to find the mass of the material to be moved and locate its center of gravity, he must apply to his foreman or mechanic for instructions.

Review Questions

1. What is the classification of loads in terms of their kind, method of stacking and slinging?
2. What types of packages do you know and what is their use?
3. What is the construction of a charging bucket?
4. What is the construction of a charger pan?
5. What is the construction of teeming ladles?
6. How is the material mass determined?
7. What is the way of locating the center of gravity of material?

Chapter III

Components of Hoisting Devices

3.1. Steel Ropes

Steel ropes are manufactured of high-strength steel wire up to 3 mm in diameter, whose ultimate tensile strength is higher than 1764 MPa. The *ultimate tensile strength* is a tensile stress per unit area of the cross section at which the sample under test is destroyed. It is measured in pascals (Pa), and megapascals (MPa).

Ropes are classified as follows (Fig. 7*a*-*g*).

1. As to cross section the ropes are divided into round and flat ones. Round ropes in their turn are classified according to a number of features. Structurally, the ropes may be single, double and triple lay ropes. Single lay ropes are made up of separate wires which are twisted into a spiral. For manufacturing double lay ropes, the wires are twisted together to form strands first and then strands are twisted to make a rope. Triple lay ropes may be one-, two- and three-layer ones. Use is also made of

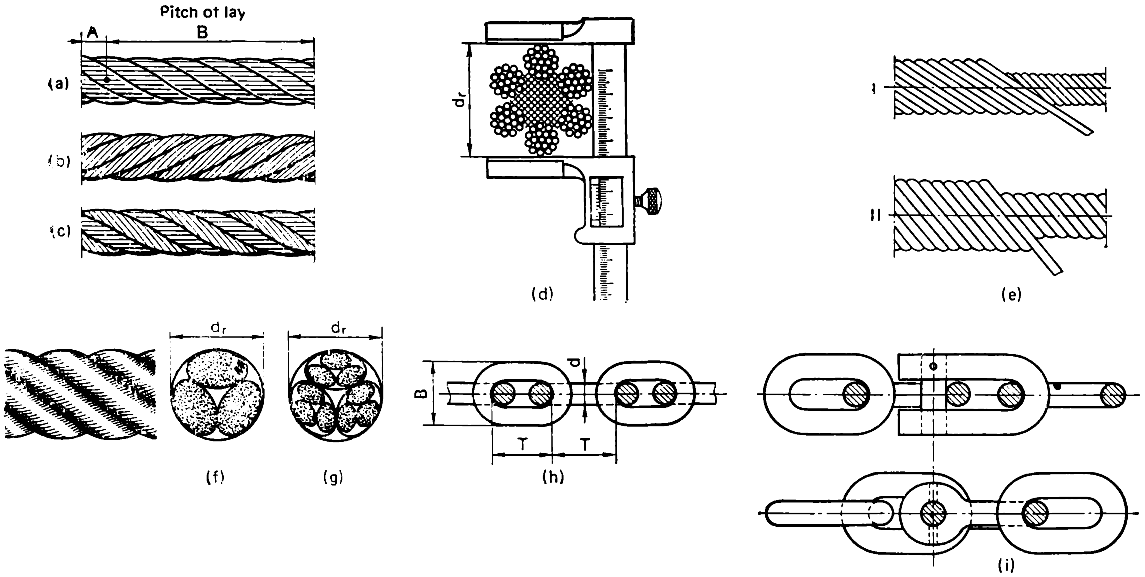


Fig. 7. Traction elements of slings:
a—regular-lay (right-hand lay) steel ropes; *b*—long-lay (left-hand lay) ropes; *c*—combined-lay ropes; *d*—rope diameter measuring diagram; *e*—ropes with point (I) and linear (II) contact of wires; *f*—ordinary hemp ropes; *g*—cable-laid hemp ropes; *h*—welded chain; *i*—lock

triple lay ropes twisted of several double lay ropes. Triple lay ropes are usually called cables.

Moreover, there may be round strand ropes and shaped strand ropes. In round strand ropes the cross section of the strands is round, while in shaped strand ropes the cross section of the strands in trihedral, oval or of some other form.

2. Depending on the way the wires are laid together in a strand, wire ropes are available in two types: with a point contact between the individual wires forming the layers in a strand (TK) and with a linear contact between the wires in a strand (ЛК). Wire ropes of the latter type are provided in a number of modifications which are:

ЛК-0, all wires forming individual layers of a strand are of the same diameter;

ЛК-Р, the wires forming the outside layer of a strand are of different diameters;

ЛК-З, filling wires of a diameter smaller than that of the rest of wires are interposed between the layers;

ЛК-РО, layers composed of wires with the same diameter alternate in the strand with layers where the wires are of different diameters.

Furthermore, the wire ropes of types ТЛК-О and ТЛК-Р are available in which the wires in the strand are both in point and linear contact.

3. With reference to the core, the wire ropes are divided into those with an organic core, with a metal soft core made of annealed steel wire, with a core of steel rope wire, asbestos cord, plastic material and other synthetic materials.

4. Depending on the method of laying, the ropes may be spinning and nonspinning ones. To prevent the rope from untwisting, its end is tied with 8-10 coils of soft wire. Such a tying is called a wire seizing. In spinning ropes the strands and wires do not retain their position after the seizing is removed from the rope end, while in nonspinning ropes they do.

5. As to the direction of lay the ropes are available in left-hand lay and right-hand lay. The lay direction is found in the following way: for spiral ropes it is indicated by the direction of lay of the outside layer, for double lay ropes it is indicated by the direction of lay of the

strands in the outside layer, for triple lay ropes it is indicated by the direction of lay of the rope strands.

6. According to the combination of the lay directions of rope elements, distinction is made between regular-lay ropes in which the directions of lay of the strands in the rope and individual wires in the strands are opposite, and long-lay ropes in which the directions of lay of the strands in the rope and individual wires in the strands of the outside layer are the same. Triple lay ropes are always regular-lay ones.

7. With reference to a degree of untwisting, ropes are also divided into spinning ropes having the same direction of lay of all the strands and nonspinning ones which are the stranded ropes having alternately opposite lays in individual layers.

8. As to mechanical properties of the wire used, there may be high-quality ropes, normal-quality ropes of the 1st and 2nd grades and seizing ropes.*

9. According to the type of the wire surface coating, distinction is made between the ropes built up of bright steel wire and those made from galvanized steel wire. The latter may have a thin zinc coating for light duty (ЛС), a medium-thick zinc coating for moderate duty (СС), a thick zinc coating for severe duty (ЖС) (to be used in chemically active media), or a polymer coating of the entire rope or individual strands.

10. Regarding the purpose, ropes are divided into ropes for hoisting people and materials (ГЛ) (to transport people only high-quality ropes are used), ropes for carrying nothing but materials (Г), and seizing ropes which are used for tying various materials.

Review Questions

1. What kinds of cores are used for steel ropes?
2. How are wire ropes divided according to the type of coating?
3. What wire ropes do you know with reference to the degree of their untwisting?

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* Seizing ropes are twisted of soft annealed wire and are usually used for tying.

3.2. Employment and Quality Check of Steel Ropes

The following ropes are used for erection work: double lay ropes with a linear contact between the wires in a strand (ЛК-0) having the following construction: $6 \times 19\,(1 + 9 + 9) + 1$ with an organic core; double lay ropes with a linear contact between the wires in a strand (ЛК-Р) having the following construction: $6 \times 19\,(1 + 6 + 6 + 6) + 1$ with an organic core; double lay ropes with a combined point-linear contact between the wires in a strand ТЛК-0 having the following construction: $6 \times 37\,(1 + 6 + 15 + 15) + 1$ with an organic core. If the ropes of types ЛК and ТЛК are not available, use is made of double lay ropes with a point contact of individual wires between the layers in a strand of the construction: $6 \times 19\,(1 + 6 + 12) + 1$ with an organic core and ropes of the construction: $6 \times 37\,(1 + 6 + 12 + 18) + 1$ with an organic core.

For example, the designation of the rope construction $6 \times 19\,(1 + 9 + 9) + 1$ with an organic core can be deciphered in the following way: a rope laid of six strands (the first figure); the second figure designates the number of wires in a strand; the figures in the brackets denote the arrangement of wires in a strand: the first figure denotes the central row, the second figure denotes the second row, the third figure denotes the third row, etc. The last figure gives the number of cores. The greater the number of wires, the thinner they are provided that the diameter of the rope is the same.

Slings are manufactured of the ropes of type ЛК-РО having the following construction: $6 \times 36 + 1$ with an organic core. In metal making, thermal treatment and other hot shops use is made of ropes with a core made of annealed steel wire or asbestos fibre. It is permissible to employ the ropes of type ТЛК-0 having the following construction: $6 \times 37 + 1$ with an organic core. All the ropes produced are provided with a certificate which contains: the name or trade mark of the Manufacturer, the rope No., its purpose, nominal diameter, description of wire coating, direction of lay, method of lay, length of the rope, degree of its untwisting, weight of the rope (gross weight), results of mechanical tests (comprising the classification group of the rope in terms of the ultimate tensile strength, the rope mark, the total tensile strength of all the wires in the rope or of the entire rope), material of the core, additional data on the rope and the date of its manufacture. Moreover, attached to the rope is a tag with the Manufacturer's data about the rope.

Should the certificate or tag be missing, a rope sample is to be tested in the laboratory and basing on the data obtained a new certificate is used and new tag is attached to the rope.

The load at which the rope is broken is called a *breaking strength of the rope.* It depends on the strength of the wires of which the rope is built up: the stronger the individual wires, the stronger the rope as a whole. Two ropes of the same construction and same diameter may have different strength. For instance, among two ropes of the same diameter with a point contact between the wires and having the same 6 × 37 construction but consisting of wires of different ultimate tensile strength, the rope whose individual wires have higher ultimate tensile strength is stronger.

In operation it is prohibited to apply to the rope a load which is close to the breaking one, since this may result in rope *breakage and accidents.*

The breaking strength of the rope may be found by breaking the entire rope or by breaking each wire of the rope and summing up the breaking strength of all the wires. It should be borne is mind that the aggregate strength of all the wires is always higher than the breaking strength of the entire rope due to uneven work of wires in the rope. In order to calculate the breaking strength of a rope, the total breaking strength of wires is to be multiplied by 0.83.

The ropes are selected taking into account a safety factor which is prescribed by official documents.

The smallest permissible safety factor of ropes is given below:

Purpose of rope	Safety factor
Hoisting and jib ropes	4.0[1]
Ditto	5.0[2]
Ditto	5.5[3]
Ditto	6.0[4]
Guy rope of a boom	3.5
Clamshell rope:	
for a clamshell having a separate two-motor drive (assuming that the clamshell weight with material is evenly distributed throughout the rope falls)	6.0
for a clamshell having a single-motor drive	5.0
for one-fall rope and motor clamshell	5.0
Guy ropes of masts and supports:	
of permanently operating cranes	3.5
of cranes having an operating life up to one year	3.0
Pull ropes used in cranes	4.0
Ropes for cam supports and for holding electric cables of cable cranes	3.0
Ropes for anchoring the load-carrying ropes of lifting tackles (of cable cranes)	6.0
Ropes for people hoisting winches	9.0
Ropes used for crane erection	4.0
Ropes used for derricking beyond the operation range	3.5
Ropes for slings used for lifting the loads with binding or hooking	6.0

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[1] Hand drive.
[2] Mechanical drive, light duty.
[3] Mechanical drive, medium duty.
[4] Mechanical drive, heavy and severe duties.

The factor of safety is a number indicating by how many times it is necessary to decrease the load on the rope as compared with the maximum load (breaking strength) in order to insure complete safety of the material in its movement. Depending on the purpose of the rope, different safety factors are established.

The rope diameter can be measured with the aid of slide calipers (see Fig. 7*d*) or by measuring the circumference length and dividing it into π (~ 3.14). To measure the circumference length of a rope at site, do the following. Loop a soft wire or a binder twine around the rope 10 times placing each turn close to another and then measure the length of this section and divide the result by 10.

The rope diameter can be calculated using the following formula:

$$d = l/\pi - 2h$$

where l is the circumference length measured and h is the thickness of the wire or binder twine.

The *pitch of lay* in rope specifications is the distance between two consecutive turns of one and the same strand measured along the rope axis.

While determining the length of lay, a mark A (see Fig. 7*a*) is applied onto the surface of one of the rope strands from which as many strands are counted as there are in the rope cross section (for example, in a six-strand rope—6). A mark B is made on the strand next to the last strand counted (in the given example, on the seventh one). The distance between the marks A and B is the pitch of lay of the rope.

Before work ropes are periodically inspected seeing to it that there are no kinks and knots, bulging or twists of the strands, signs of surface wear, broken strands or individual wires. Steel ropes in use built up of the wires of one and the same diameter are rejected according the number of breaken wires observed within a pitch of lay in compliance with the code requirements tabulated in Table 2. Subject to disregarding are also worn, corroded and mutilated ropes as well as those having dents and broken strands.

The fitness of the rope used earlier is checked in the following way: the rope diameter is measured to an accuracy of 0.1 mm, then the pitch of lay is found; the number of broken wires is counted within the entire pitch of lay (suppose there are 11 breaks) and the original safety factor is determined (in case of sling ropes it is more than 6); using Table 2, it is found that the rope of given construction having such a safety factor must be rejected if it has 13 broken wires; therefore, the rope is still fit for work provided there are no additional defects such as nicks, corrosion and the like.

The rope is discarded if a strand is discontinuous. The surface wear or corrosion manifests itself in the reduction of the rope diameter, the latter being measured by means of a micrometer or slide calipers. If the certificate says that the wire diameter is 1 mm, but the measurements give 0.9 mm, the surface wear or losses due to corrosion are

$$(1 - 0.9)\cdot 100 = 10\%$$

Table 2. The Code Requirements for Rejection of Steel Ropes by the Number of Broken Wires within a Pitch of Lay

Rope construction	Original safety factor at *D* and *d** prescribed by the Code		
	6 ≪	> 6 ≪ 7	> 7
6×19=114+1 o.c.**:			
regular-lay	12	14	16
long-lay	6	7	8
6×37=222+1 o.c.:			
regular-lay	22	26	30
long-lay	11	13	15
6×61=366+1 o.c.:			
regular-lay	36	38	40
long-lay	18	19	20
18×19=342+1 o.c.:			
regular-lay	36	38	40
long-lay	18	19	20

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* *D* is the diameter of the drum, mm; *d* is the diameter of the rope, mm.
** o.c. stands for an organic core.

If in addition to wire breaks the rope has a surface wear or corrosion and also nicks or mutilations, the number of wire breaks calling for rope rejection is reduced in accordance with data given below

Decrease of the wire diameter as a result of surface wear or corrosion, %	10	15	20	25	30 and more
The number of wire breaks within the pitch of lay, in per cent of the code requirements indicated in Table 2	85	75	70	60	50

Ropes of hoisting machines designed for people lifting are rejected by the number of breaks of wires within a pitch of lay which is twice as less as that indicated in Table 2. In case of wear or corrosion amounting to 40%

or more, the rope should be rejected. While examining the ropes made of wires of different diameters, a break of a thin wire is assumed to be 1 and a break of a thick wire is assumed to be 1.7. If within a pitch of lay of the rope having an original safety factor more than 6, four thin wires and five thick wires are broken, the number of breaks of the rope wires is assumed to be equal to $4 \times 1 + 5 \times 1.7 = 12.5$, and the number of wire breaks which calls for rope rejection is 13. Therefore, this rope can be used provided that it has no surface wear or corrosion of the wires.

Ropes designed for carrying molten metal or red hot items, explosive, inflammable and poisonous materials, are rejected if the number of wire breaks is twice as less as that indicated in Table 2, taking into account the code requirements for rope rejection due to surface wear or corrosion.

Before sending ropes to the customer, steel ropes are marked and packed. As a rule, ropes are coiled about a drum. For rope rewinding use can be made of reels (drums) whose diameter is not less than 15 diameters of the rope. The drum flange must protrude beyond the outer layer of the wound rope of up to 25 mm in diameter by a length equal to two diameters of the rope, and if the rope diameter is more than 25 mm, by a length not less than 50 mm.

Review Questions

1. How is the rope strength determined?
2. What is the safety factor of the rope?
3. How is the ultimate strength of the rope determined?
4. What are the reasons for rope rejection?

3.3. Steel Welded Chains

For heavy duty operations in metallurgical practice, in thermal treatment, casting and other hot shops use is made of steel chains alongside with steel ropes. They are employed as slings and lifting gear for pulling and driving mechanisms of hoisting machines. Slings and lifting gear are fabricated from ordinary welded chains made of soft alloyed round steel having a fine-grain structure and yield strength of 370-450 MPa. The links are of an oval shape and arc- or gas-welded. With reference to the length of links the chains are divided into short-link chains having the link length $l \leqslant 5d$ and long-link ones having the link length $l > 5d$. The specifications of short-link chains are given in Table 3.

Table 3. Specifications of Hoisting Chains

Chain gauge	Breaking strength (minimum), kN	Width, mm	Pitch, mm	Weight of 1 m, kg
6	13.7	21	18	0.75
7	17.6	23	22	1.00
8	25.5	27	23	1.35
9	31.4	32	27	1.80
10	39.2	34	28	2.25
11	45.1	36	31	2.70
13	64.7	43	36	3.80
16	100.0	53	44	5.80

For load lifting it is recommended to use cheap ordinary short-link chains which feature great deviations from the nominal size in length, width and diameter of a link cross section. While lifting very heavy loads, long-link chains with studs called anchor chains are allowed to be used.

Chains are selected similarly to ropes according to the operating conditions. Safety factors are prescribed by the state official documents.

Safety factors for welded and stamped chains are given below:

Purpose of chains	Manual drive	Power drive
Load chain winding on a smooth drum	3	6
Load chain winding on a sprocket (calibrated)	3	8
Chains for slings	5	5

A permissible wear of a welded chain link is not more than 10%. Chains used for hoisting machines and for slings must have the Manufacturer's test certificate. If the certificate is missing the chains are to be tested to determine permissible lifting load. Used for binding the load to be lifted are chain slings since they have longer life as compared to rope slings, better follow the load configuration and show less wear when bent over sharp corners and edges of the load. Chains are interconnected by means of electric arc, gas and forge welding, by introducing new links or with the aid of special couplers (Fig. 7*i*).

Review Questions

1. What material is used to fabricate welded chains?
2. What are the advantages of welded chain slings over rope slings?

3.4. Hemp and Synthetic Fibre Ropes

Hemp ropes are used less commonly than steel wire ropes. They find use as guy ropes and slings for lifting articles of small weight but of large size. Hemp ropes are lighter than steel wire ropes, cheaper and the process of their fabrication is less labour consuming but their strength is much smaller (the diameters being the same, a steel wire rope is 10 times stronger than a hemp one). Hemp ropes (Fig. 7*f*, *g*) are twisted of yarns made of long hemp fibre. Yarns are twisted to form strands, and three strands are laid to make a rope having, as a rule, a right-hand lay. Ropes can be tight-twisted and loose-twisted. Tight-twisted ropes are stronger but due to their rigidity they are seldom used for slinging. Depending on the yarns used, distinction is made between tarred ropes and white ropes. Tarred ropes are waterproof but they are heavier than white ropes and not so strong (by 5-10%). White ropes are prone to ablation.

Depending on the quality of the stock material used and on the purpose of finish, hemp three-strand white and tarred ropes are divided into special-purpose, improved and ordinary ones. Drive ropes, slings, guy ropes are always white ropes.

The main characteristics of hemp ropes are the diameter and tensile strength, working load and safety factor. For hemp slings the safety factor must be not less than 8.

When packing the Manufacturer rolls the ropes into coils and tightens them in four places by binders whose ends are brought inside the coil. To prevent ropes from untwisting, the rope ends are tightly bound over a length from 2 to 5 cm depending on the rope diameter. Each coil is provided with a metal tag which bears information about the name and group of the rope and the date of manufacture. Coils weighing up to 100 kg are covered with packing cloth. Each packed coil of ropes carries a plywood or cardboard tag with the name of the Manufacturer, marking of the rope, coil No., length of the rope in the coil, gross weight, date of manufacture, QCD stamp, and the state standard according to which the rope is made. Rope coils should be stored in dry closed warehouses away from direct sun rays, oil, gasoline and other solvents. Ropes must be placed indoors at a distance of not less than 1 m from heating devices.

Lately the ropes made of synthetic fibres (capron, perlon, etc.) are being used. The strength of such ropes is much higher than that of hemp ropes. They are not liable to decay and do not get soaked.

Capron ropes are manufactured of polycaprolactam fibre twisted into yarns and then into strands. Capron ropes like hemp ropes are twisted of three strands and have a diameter from 7.9 to 63.7 mm. For capron ropes manufactured by the industry the following deviations are permissible, %:

With reference to the rope circumference length in a free state after production for all the sizes	±6
With reference to the rope circumference length in a free state in case of long-term storage for ropes having a diameter within the range:	
from 25 to 90 mm	±12
from 100 to 200 mm	±8
With reference to the number of coils per 1 m of the rope	±6
With reference to the number of yarns in the rope having a diameter from 50 to 200 mm	±3
With reference to the rope weight for 100 m	±6

The rope circumference length is measured as required by a steel measuring tape 5 mm wide or with slide calipers. All in all ten measurements are taken at different places of the coils selected for testing. The distance between the test points must be not less than 2 m.

The total number of turns is determined by counting them at three points over a length of 1 m and taking an arithmetic mean. In order to determine the number of yarns and the weight of the rope, a sample piece 2 m long is cut off from the coil and the number of yarns is counted in the sample.

Manufactured ropes are delivered to customers in coils or wound about wooden drums. The coils are tied in four places with binders whose ends are brought inside the coil.

At metallurgical works hemp ropes and ropes made of synthetic fibre are used very seldom and anywhere but not in hot shops.

The characteristics of ordinary hemp tarred ropes are the following:

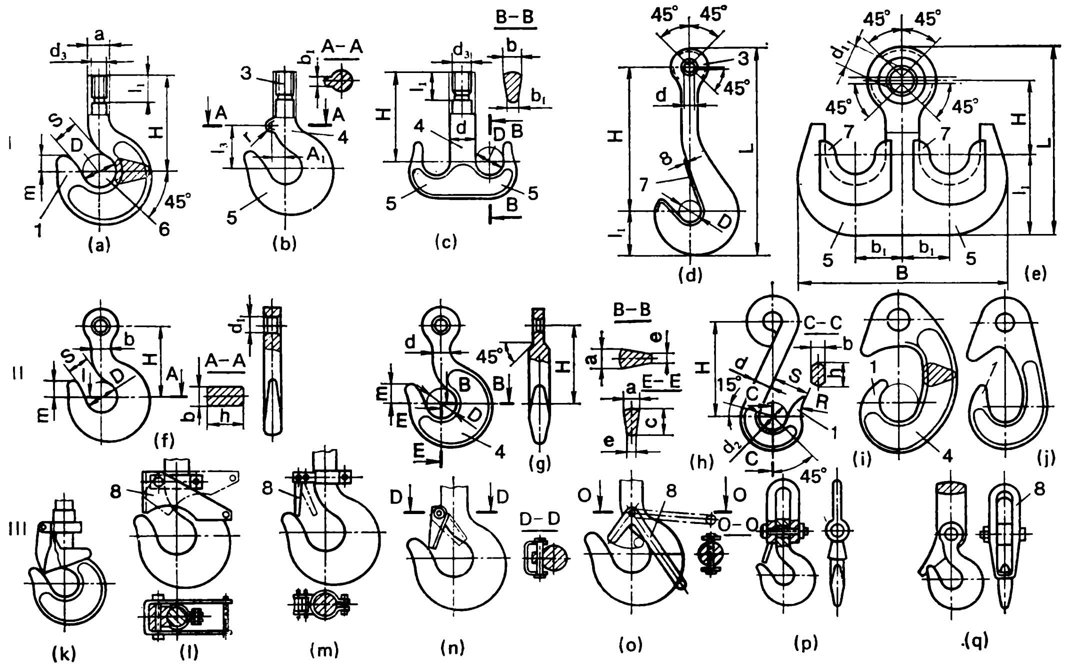
Approximate diameter, mm	Breaking load, kN, (minimum)	Approximate diameter, mm	Breaking load, kN, (minimum)
10	5.9	26	32.9
11	6.9	32	49.8
13	9.2	37	62.4
14	11.3	40	63.8
16	14.5	48	101.1
19	19.5	56	131.7
22	26.5		

Review Questions

1. What ropes are used for making slings?
2. Where are hemp and synthetic fibre ropes used?

3.5. Hooks

Hook is a multi-purpose gripping appliance which is widely used as a working member of hoisting mechanism (load cranes) and as an end element of slings and other lifting devices (Fig. 8).


I
II
III
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
(j)
(k)
(l)
(m)
(n)
(o)
(p)
(q)
A–A
B–B
C–C
D–D
E–E
O–O
H
L
D
S
m
a
d_3
l_1
l_3
A_1
b_1
d_1
d_2
45°
15°
R
1
3
4
5
6
7
8

Depending on the shape, hooks fall into single (ordinary-pattern) hooks and sister (ramshorn) hooks. By the method of fabrication hooks are divided into forged and stamped ones; the hooks may also be composite, welded, and laminated. Forged (stamped) hooks are available with short shanks (type A) and with long shanks (type B). These hooks are manufactured of steel 20 or 20Г.

Single laminated hooks are designed for casting cranes, while sister hooks are employed on general-purpose cranes with a lifting capacity of 40-320 tonnes. Laminated hooks are made of steel 20 and M16C; hooks used at a temperature below —40 °C are manufactured of steel 09Г2C in a normalized state.

The hooks utilized as end elements of slings and the like attachments are forged or cut of steel plates; they are favoured for ease of fabrication and reliable operation. But as regards operational properties and structural peculiarities, preference is, however, given to forged hooks at metallurgical works.

In some cases hooks of a special form are made which can be used, for instance, as eccentric grapples. It is good practice to provide the gripping facilities with a lifting capacity of up to 350 kg with light-duty hooks made of round hot-rolled steel 20 (Table 4). Fabrication practice for such hooks is simpler than that for forged or stamped ones.

To prevent a below-the-hook attachment from accidental coming off the hook, the latter is provided with

Fig. 8. Hooks:
I—crane hooks; II—sling hooks; III—hooks (forged and stamped) with safety devices; *a*—single hook; *b*—single hook with a boss; *c*—laminated sister hook; *d*—single hook; *e*—sister hook; *f*—simplified hook of a rectangular cross section; *g*—simplified hook of a trapezoidal cross section; *h*—simplified hook made of rod; *i*—hook with a safety nose; *j*—hook with a deep mouth; *k*—hook with a safety bar; *l*—hook with a locking clamp; *m*—hook with a spring-loaded latch and a yoke; *n*—hook with a spring-loaded latch attached to the hook boss; *o*—hook with a latch closed by the force of gravity; *p*—hook with a side latch closing the mouth when the rope is tightened; *q*—hook with a front latch closing the mouth when the rope is tightened; *1*—nose tip; *2*—mouth; *3*—hook tail portion; *4*—hook shank; *5*—nose; *6*—trunnion; *7*—protective insert; *8*—safety devices

Table 4. Technical Characteristics of Forged Light-duty Sling Hooks Made of Rods

Load-lifting capacity, kg	Dimensions, mm									Weight, kg
	d	d_1	d_2	H	L_1	S	R	b	h	
70	11	14	16	75	35	23	35	8	14	0.16
100	13	16	20	75	40	28	40	10	16	0.24
150	16	20	25	85	50	35	45	12	20	0.43
200	20	25	30	90	65	42	50	15	25	0.80
350	26	30	35	110	80	52	55	18	32	1.70

a safety device (see Fig. 8). Such devices are not installed on the hooks of gantry cranes used in sea ports, cranes carrying molten metal or liquid slag, and also the hooks to which the load is attached by means of flexible lifting attachments. It is mandatory to provide with the safety devices hooks of hoisting cranes used for mounting the equipment or carrying the materials in containers, buckets and other packages and also in case of employing rigid slings and grapples. Hooks of hoisting mechanisms and lifting attachments must have a clean surface without burrs, pin holes, sharp corners, cracks, backfins and undercuts on a carefully machined shank. The hook shank thread should have no mutilation and dents. Removal of hook defects by stuffing or the like methods is prohibited.

Hooks must be of a regular shape. It is necessary that the shank and hook tip lie in one and the same plane. During shipment of the hooks the machined parts of the shank and the thread should be protected against damage with the aid of paper or cloth impregnated with grease.

Stamped on each hook are the Manufacturer's serial No., load capacity, QCD stamp and trade mark. The hook is provided with a certificate containing information about its main features and the test data.

In operation the wear of the hook in the mouth must not be more than 10% of the original height of its cross section. Bent hooks should be rejected.

Laminated hooks are manufactured of separate steel plates (Cт3 or steel 20) whose thickness is not less than 20 mm which are cut out to a template and interconnected by riveting. Laminated hooks are less complicated in fabrication, do not require powerful press-forging equipment and are more reliable in operation than forged counterparts. Bronze inserts or steel half-bushings are provided in the mouths of laminated hooks to protect them against abrasion and preserve ladle trunnions.

Review Questions

1. What kinds of hooks are used in metallurgical practice?
2. What is the design of laminated hooks?
3. What steels are used for hook fabrication?

3.6. Business-end Tools, Legs and Members of Slings

Business-end tools are used for attaching slings to a lifting gear of hoisting mechanisms, for coupling the parts of slings and for securing the slings to special accessories on materials provided for their hoisting and hauling. Business-end tools of slings are made of the following types: triangle split links (of three embodiments); oval split links; triangle, ovoid, oval (of two embodiments) solid links; hooks with locks, hooks without locks, hooks with flush-type nose, snap hooks, etc.

Thimbles (Fig. 9) are widely used as business-end tools. They are selected with reference to the rope diameter irrespective of the rope features. A thimble is a metal channel bent to form a ring. In this country two types of thimbles are manufactured: for steel ropes and for hemp ropes. For synthetic fibre ropes use can be made of the thimbles intended for hemp ropes. Thimbles are stamped or forged with subsequent bending and zinc coating. The marking on thimbles indicates the Manufacturer's trade mark, type of the thimble, and permissible load.

Solid rings are fabricated by bending steel rods with the joint subsequently welded up (Fig. 10). Used more often are oval rings since they are easily centerable with reference to a hook and various projections; triangle rings are most suitable for work with flat slings; round rings are not used for lifting heavy loads since they have great diameters.

The disadvantage of closed rings is that they cannot be disassembled for changing slings or for repairs. Most suitable in operation are split rings; snap hooks, stirrups, shackles with a detachable strip.

A *snap hook* is an elongated half-closed ring with a closing mouth (Fig. 11). Snap hooks may be permanently connected to the sling and detachable. The permanently connected snap hook is an integral part of a sling, while the detachable snap hook is fitted on the sling loop and

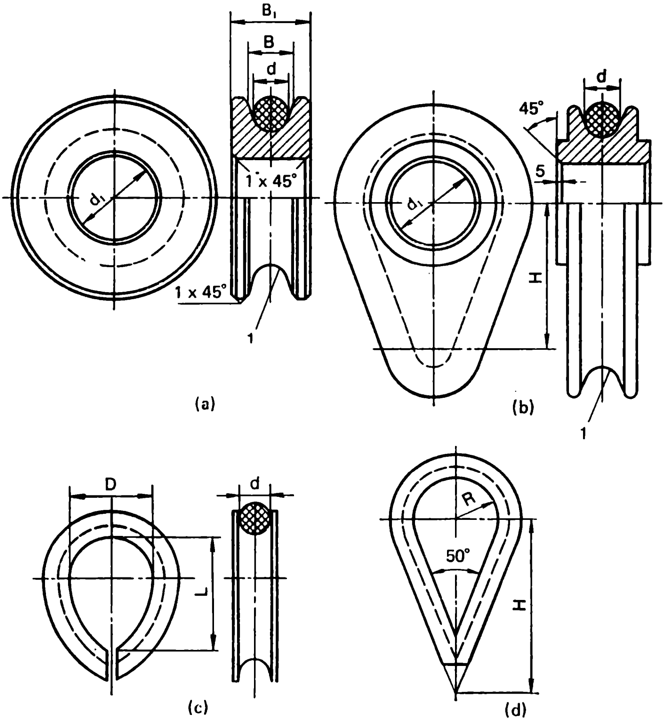


Fig. 9. Thimbles:
a—eyelet thimble; *b*—cast thimble; *c*—forged and stamped thimbles; *d*—thimbles made of tubes (*1*—thimble notch)

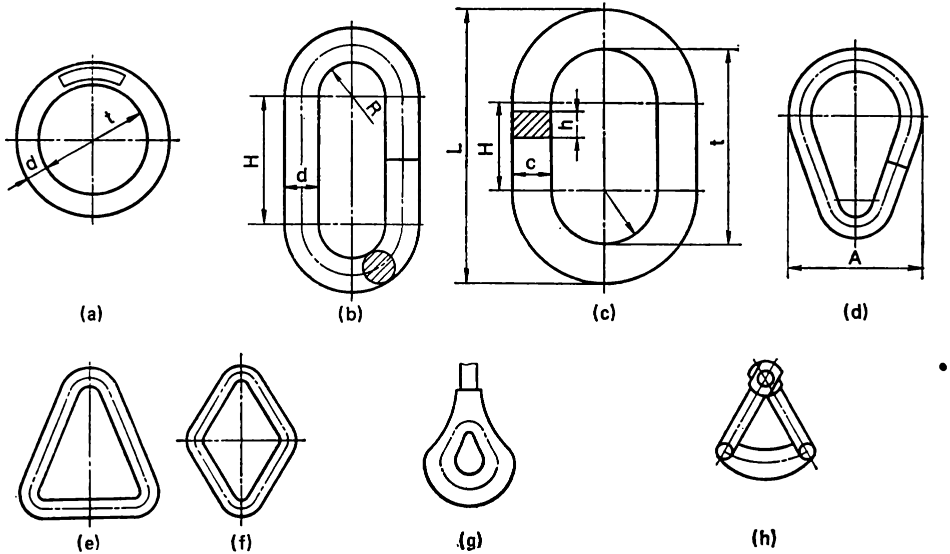


Fig. 10. Solid rings:
a—round ring; *b*—oval ring of round cross section; *c*—oval ring of rectangular cross section; *d*—ovoid ring; *e*—triangle ring; *f*—rhombic ring; *g*—forged ring; *h*—hinged ring; *d*—diameter of a link; *t*—pitch of a link; *R*—inner radius of an oval ring; *H*—distance between oval centers; *L*—length of a link; *C*—width of a rectangular cross section; *h*—thickness of a ring having rectangular cross section; *A*—width of a link

can be easily removed, if necessary. The ring mouth of snap hooks is closed with a safety tube or plate preventing the load and the sling from accidental coming off the ring. A permanently connected snap hook is prevented from coming off the sling ring by means of a safety strap. The safety plate of a detachable snap hook is retained on the ring by a pin. Before the material is slung the safety tube or plate is raised so as the snap hook ring can easily catch the loop, eye or ear of the material to be hoisted. Snap hooks are safe in work and can be used for slinging any kind of materials. If snap hooks are in good order, no inadvertent disconnection occurs.

Two coupled hooks resembling the letter S in shape are called *S-member* (Fig. 12). In practice two types of S-members are used: ordinary and elongated. The S-members are bent of steel rods. They are designed for lifting light-weight loads. Forged or stamped elongated S-members are used for hoisting loads weighing up to 3000 kg. The S-members with turnbuckles are also manufactured

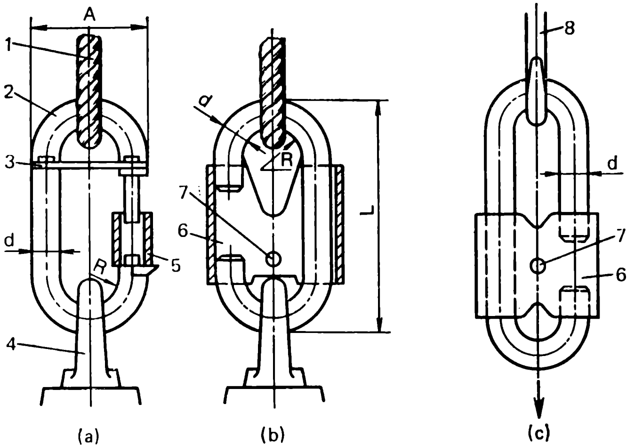


Fig. 11. Snap hooks (split rings):
a—permanently connected snap hook; *b*—detachable snap hook; *c*—elongated detachable snap hook; *1*—rope; *2*—link; *3*—safety strap; *4*—eye; *5*—safety tube; *6*—safety plate; *7*—retaining pin; *8*—crane hook, *A*—snap hook width; *d*—diameter of a link cross section; *L*—length; *R*—inner radius

by forging or stamping. They are used for hoisting light-weight and heavy-weight loads. When slinging the load by means of an S-member, one hook is secured to the sling and the other hook is used to catch the load. For this purpose chain slings with elongated links or additional rings are employed. They allow to secure several items to one sling leg. The S-members with turnbuckles (sleeves) can be adjusted on length and this is very important when mounting the items strictly vertically or horizontally. When using S-members, it is necessary to see to it that before hoisting the load the slings are well tightened otherwise an accidental detaching may take place.

Rocker is the most simple and at the same time multipurpose device. It is very simple in fabrication and useful in work. Rockers can be made to lift from several kilogrammes to 80 tonnes (Fig. 13).

Ordinary rockers are employed for slinging light-weight and heavy-weight items; bent rockers are used for slinging light-weight materials; round-bar rockers with flats are used to sling very heavy items. Stirrups welded to rockers prevent the rope from slipping off. Round-sha-

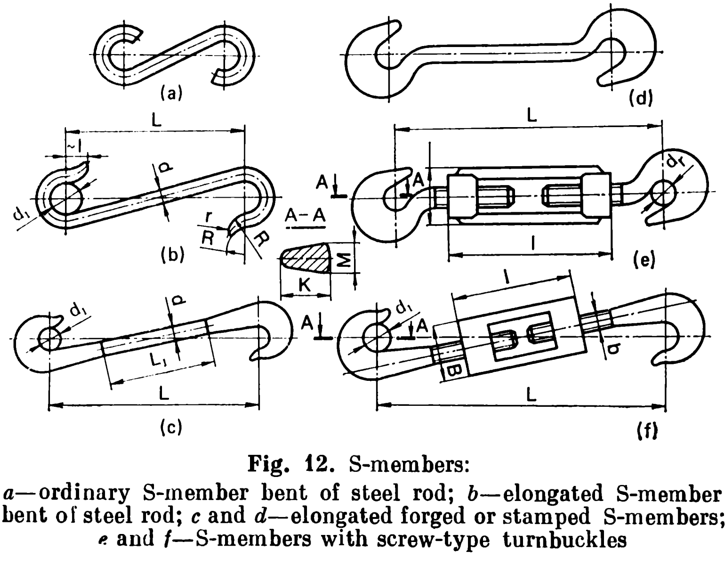


Fig. 12. S-members:
a—ordinary S-member bent of steel rod; *b*—elongated S-member bent of steel rod; *c* and *d*—elongated forged or stamped S-members; *e* and *f*—S-members with screw-type turnbuckles

ped rockers with shoulders attached to general purpose slings are applied for slinging medium-weight items; multi-stepped rockers and rockers with eyes are used for assemblying cylinders and other components when they are to be centered; cone-shaped rockers find use in slinging tapered parts; hook-type rockers are used for hoisting parts having equal weight. While selecting a rocker, it is necessary to take into account the fact that its length must be 10-20 mm greater than the hole in the item into which the rocker is inserted. If the hole in the item is larger than the rocker arm the latter may slip out of the hole and the item will break away from the sling. The minimum diameter of the hole in the item to be lifted must be 120 mm to enable the slinger to insert the rocker, turn and disconnect it by hand. If the hole in the item is small or the rocker is heavy, a rope is fastened to it for turning the rocker around from outside to prevent the worker's hand from pinching.

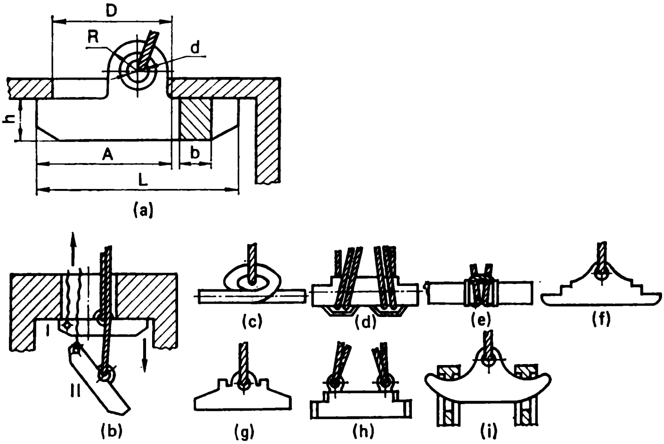


Fig. 13. Rockers:

a and *b*—ordinary rockers for slinging light-weight and heavy-weight loads; *c*—bent rockers for slinging light-weight loads; *d*—round-shaped rocker with flats for very heavy loads; *e*—round-shaped rocker for heavy-weight loads; *f* through *h*—multi-stepped rocker with an eye for slinging tapered items; *i*—group-type rocker for slinging several items having equal weight; I—lifting position; II—slinging and unslinging position

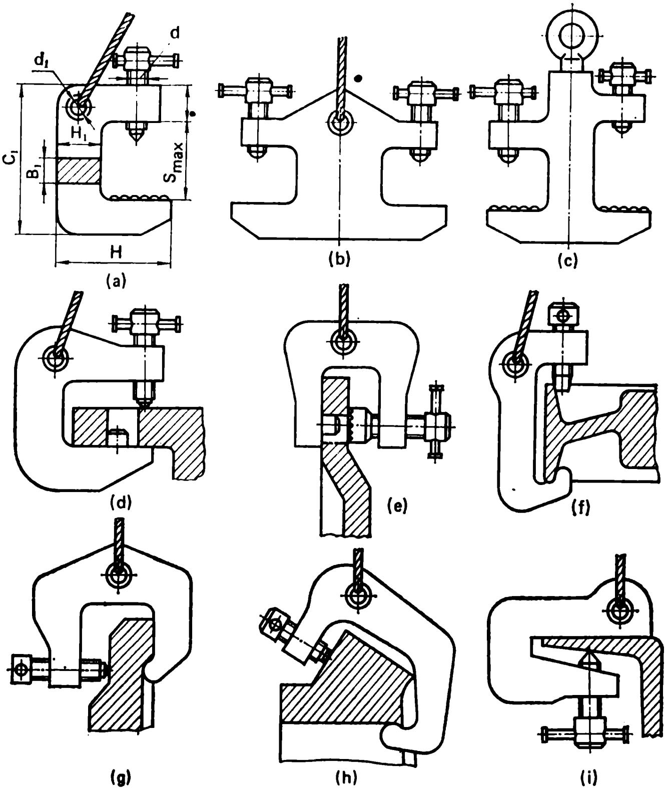


Fig. 14. Lifting cramps:
a—single-side cramp; *b* and *c*—double-side cramp; *d* and *e*—special-purpose cramp with a pin; *f*—cramp for gripping the pulleys; *g*—cramp for gripping the gears; *h*—cramp for gripping the bevel pinions; *i*—cramp for gripping the items having wide horizontal shelves

Lifting cramp consists of a frame and a tightening screw with a knob (Fig. 14). The contact surfaces of the cramps having no special projections must be serrated or faced with hard-alloy ribs. Lifting cramps are provided with holes to receive a ring or a sling rope. The frame shape is dictated by the purpose of the cramp. Ordinary multi-purpose cramps are designed for gripping the items in a horizontal position. Double-sided cramps are used for slinging the parts having flat surfaces and slot-type holes into which the cramp is inserted and secured with screws, all this adding to strength and reliability of the grip. Special-purpose lifting cramps with pins are applied for gripping the flanged items in any positions. Cramps for careful gripping of pulleys, gears, covers and other similar parts are provided on one side with special bends (tips).

Lifting cramps are feasible for gripping the items and articles having wide horizontal shelves. To prevent the cramp frame from excessive strains, it is recommended not to overtighten the cramp screws; the screws are to be normally tightened by hand with the aid of a screw knob. It is prohibited to make use of additional levers for screw tightening. Vertical transportation of items with the use of the cramps not provided with pins, bends, and projections, is not allowed, since the part being lifted can break down. Cramps having a stripped thread on the screws, a spread frame or a bent pin are rejected and delivered for repair.

To interconnect the rope ends and chain links and to connect a sling to brackets and eyebolts, use is made of *stirrups* (Fig. 15). For steel ropes two kinds of stirrups are manufactured: with a threaded pin and with a smooth pin, while for hemp ropes, only with a threaded pin. Stirrups have a straight eyebolt which is locked with a pin after a rope loop or a chain link is brought through. Stirrups with smooth pins are designed for a permanent connection of the rope ends operating under comparatively light duty.

Stirrups are fabricated of low-carbon structural steel and pins for them, of high-quality steel by stamping or forging with subsequent galvanizing. The marking on the stirrup side comprises the manufacturer's trade mark, type of the stirrup, and its permissible load.

Straight stirrups are used as members of load beams, grapples, guy ropes, etc. Bent light-duty and reinforced stirrups are employed instead of rings for suspending steel and hemp ropes and slings from the crane hook. Stirrups are also used as intermediate members in lifting attachments. The possibilities of application of stirrups as in-

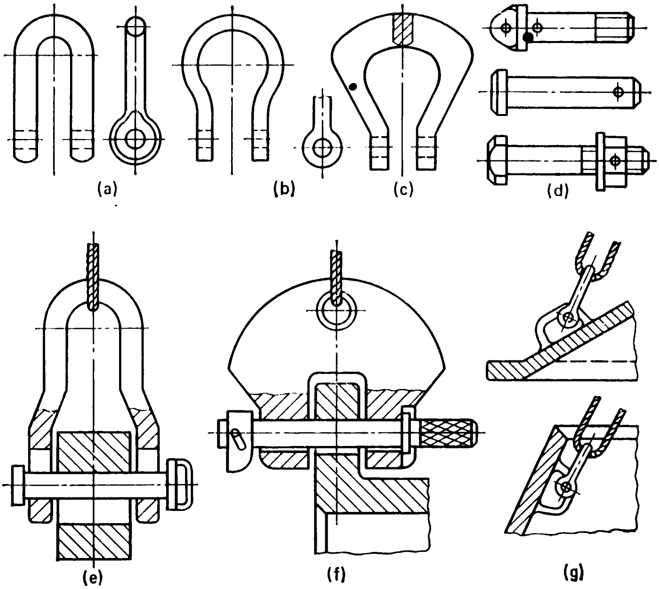


Fig. 15. Stirrups:
a—straight stirrup; *b*—bent light-duty stirrup; *c*—bent heavy-duty stirrup; *d*—stirrup pins; *e* through *g*—examples of using stirrups as independent lifting attachments

dependent elements for gripping the items are unlimited. They are used for conveying and tilting the component parts weighing up to 30 tonnes.

When slinging materials with the aid of stirrups one should see that their pins are properly cottered and nuts are tightened. If the crane hook enters a stirrup tightly or incompletely, it is strictly prohibited to hoist such a load.

The stirrup and the pin should bear one and the same mark.

Review Questions

1. What does the term "business-end tools of a sling" comprise?
2. What purpose are rings used for?
3. What steel is used to manufacture business-end tools?
4. In what cases are snap hooks used?

3.7. Grabs, Clamps, and Lifting Accessories

Tongs-type grabs comprise two legs connected like scissors by a common axle or housing (Fig. 16) and the links connecting the legs to a ring which is fitted on the hook of the hoisting mechanism. The force with which the legs are pressed against each other when lifting the load with the grabs depends on the material weight, leg-to-leg arm ratio, configuration of the item being lifted and on the pull angle. The lifting force of the grabs is proportional to the force with which the legs are pressed against each other and to the force of friction between the material being lifted and the gripping jaws.

Grabs are convenient in operation and quick in gripping and releasing the item. Changing the length of the gripping portion of the legs makes it possible to convey

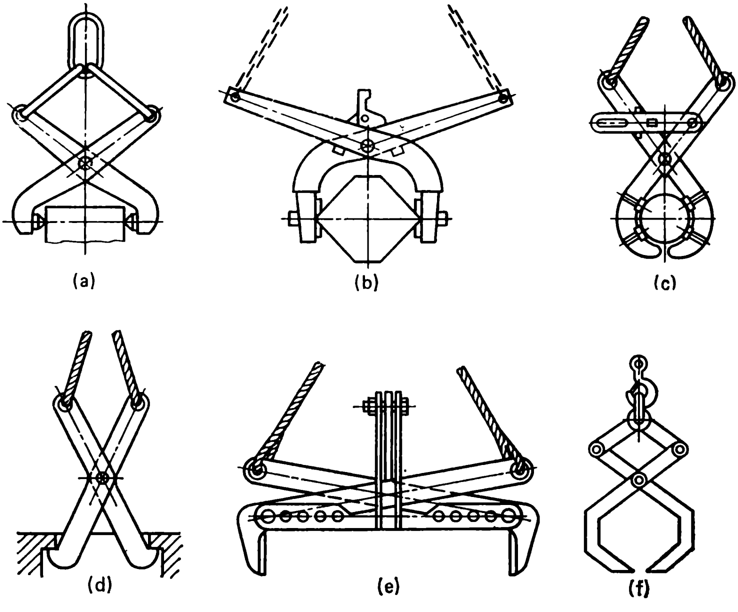


Fig. 16. Tongs-type grabs:
a—grab with pricks on gripping jaws; *b*—grab with recesses on gripping jaws; *c*—grab with shaped legs to grip round articles; *d*—grab with outwardly shaped legs to grip articles by holes or windows; *e*—adjustable grab; *f*—grab for off-size scrap

the materials of different shape and size. Grabs are widely used in metallurgical, press-forging and casting practice for transporting ingots, cast billets, forgings, etc.

Grabs are especially convenient for placing hot items into a furnace and for delivering articles to hammers and presses for processing.

A common disadvantage of grabs is the possibility of inadvertent opening of their mouth and releasing of the load as soon as the load encounters an obstacle or the surface of an unloading site.

To prevent the load from accidental release the grabs are provided with special clamps and locking devices.

To provide reliable gripping, it is necessary that the coefficient of friction between the gripping jaws and the surface of the load being gripped is not less than the following values:

For jaws against metal:	
smooth	0.12-0.15
serrated	0.5-0.6
For smooth jaws against wood	0.3-0.35

Grabs of a common use hold the load with the aid of pricks penetrating into its body or with the help of jaws with recesses. Gripping portions of the grabs designed for hoisting round parts must be curved and provided with special strips preventing a longitudinal skew of the load. The grabs used for lifting items by shoulders, grooves and holes are very simple in construction and reliable in operation. More often the legs are bent outwardly. Grabs with pricks are used to hoist the ingots by pit furnace cranes and by ingot-stripping cranes.

Whereas in forge and metal-making shops the grabs are allowed to be used practically everywhere, in mechanical shops they can be used only as an exception when some components cannot be gripped by other devices. Grabs are made use of in areas with low concentration of people and equipment, such as at storage places of metal, when loading railway cars, when mounting and placing articles on a marking-off plate, etc. Parts are allowed to be fed to the machine tools only with the help of the grabs provided with safety devices. Parts whose dimensions are greater than the maximum width of the mouth stamped on the grabs are not allowed to be hoisted. Any spacers under the jaws of the legs are strictly prohibited. Should it be necessary to use spacers, they must be rigidly secured on the grabs and tested under load. The parts are to be grasped by the grabs throughout the entire height of the jaws across the center of gravity of the load. The grabs are usually designed to carry only one item or part at a time. Materials are allowed to be taken by the grabs having sound jaws or sharp pricks. It is poor practice to use grabs for gripping ground or polished articles. The materials are not allowed to be carried by grabs at a height more than 0.6 m from the floor level of the shop.

NEVER convey the materials by grabs over people and expensive equipment.

Eccentric clamps are used as business-end tools of slings, load beams and other attachments. They comprise a frame and a grip with an eccentric jaw interconnected by an axle (Fig. 17). Eccentric clamps are designed for handling flat articles and their most frequent use is to convey metal sheets. To transport steel plates in a vertical position, one-way and two-way clamps are used which can be attached to multi-purpose or light-duty slings, multi-leg slings, and load beams. Metal plates are gripped and held in eccentric clamps due to forces of friction acting on the part being carried at the place where the plate is pressed against the clamp leg by the eccentric jaw. The developed pressing force is directly proportional to the weight of the part being lifted, therefore such clamps are referred to as self-closing devices. In case of the vertical movement of a plate, it is necessary to create in the clamp before lifting a small initial tension of the grip by hand. Other structures of the clamps do not require such manual pretensioning.

Wedge-type grips are designed for gripping the articles of a conical shape and those having deep holes or a cavity. The grip includes special spreadable members and a wedge (Fig. 18). The spreadable members are inserted into a hole of the part and a wedge is sandwiched between them; during lifting, the spreadable members hold the part tightly. Depending on the construction of the grip and of the part, the latter can be hoisted by a wedge or by spreadable members.

Eyebolt is a steel ring with a threaded stem which is screwed into appropriate holes in machine parts to lift them for mounting, movement and disassembly. Eyebolts permanently secured in the machine parts are their integral components and those working as load-gripping devices are an integral part of lifting attachments. Standard eyebolts (Fig. 19) are attached to electric motors, redu-

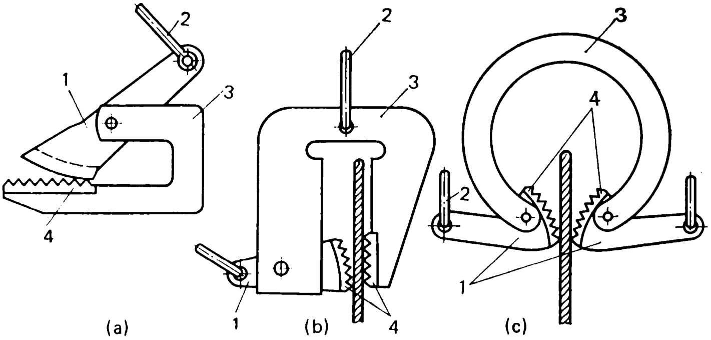


Fig. 17. Eccentric clamps:
a—one-way clamp for moving sheets in the horizontal position; *b*—one-way clamp for moving sheets in the vertical position; *c*—two-way clamp for moving sheets in the vertical position; *1*—grip with eccentric jaws; *2*—attachment ring; *3*—frame; *4*—gripping jaw

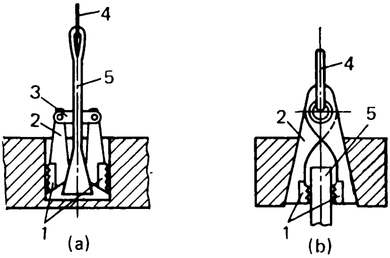


Fig. 18. Wedge-type grips:
a—grip holding the item by cylindrical and blind holes; *b*—grip holding the item by tapered holes; *1*—gripping jaws; *2*—spreadable members; *3*—connecting link; *4*—attachment ring; *5*—wedge

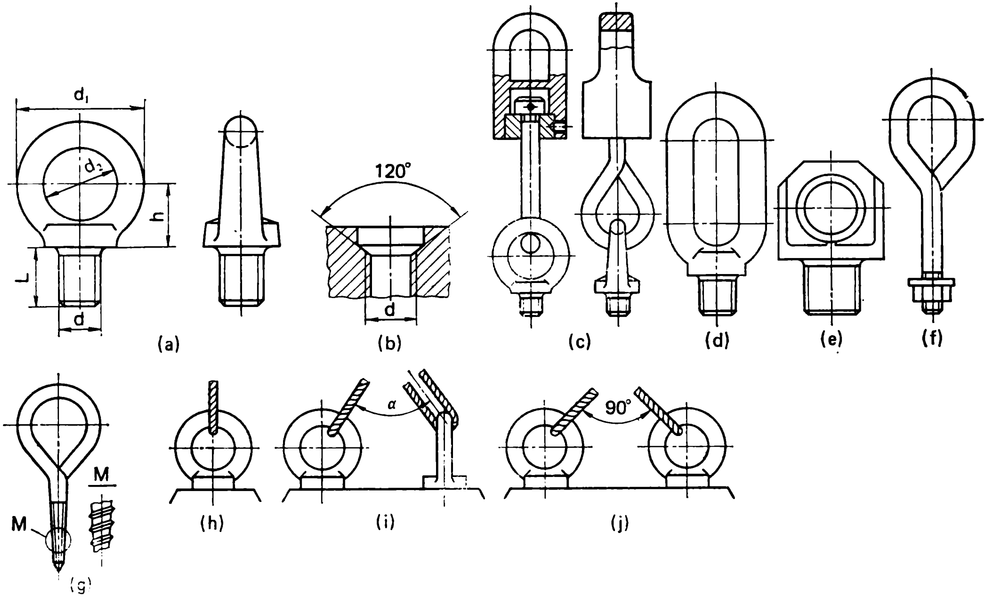


Fig. 19. Eyebolts:
a—standard eyebolt; *b*—hole for an eyebolt; *c*—eyebolt with a swivel for moving light-weight items; *d*—eyebolt with an elongated ring for moving heavy-weight items; *e*—reinforced eyebolt for tilting items; *f*—eyebolt with an elongated stem for lifting items with smooth holes; *g*—eyescrew for moving wooden items; *h*—slinging by one eyebolt; *i*—slinging by two arbitrarily arranged eyebolts; *j*—slinging by two eyebolts arranged in one plane

ction gear housings, etc. Using various adapters with inner and outer thread or with flanges, eyebolts can be used for slinging various materials (parts, assemblies and equipment). When engaging the eyebolts with sling hooks, one should take into consideration the angle between the stretched legs of the sling, the number of eyebolts and legs since at great inclination angles of legs the eyebolts are exposed to heavy loads. Unless otherwise specified, the slings should be arranged vertically. Bent eyebolts and those with stripped thread are liable to rejection.

In slinging practice at metallurgical works use is often made of *lifting pins* (Fig. 20, Table 5), as an auxiliary gripping means for multi-purpose and light-duty slings. Material slinging by means of lifting pins is cheaper as compared with other methods of slinging. When properly selected and skilfully used, the slinging of materials with the help of pins is quite reliable and safe. Pins are manufactured of low-carbon constructional steel. To facilitate the slinging, the pins having the diameter more than

Table 5. Characteristics of Lifting Pins

Dimensions, mm							Weight, kg
d	*D*	*L*	*l*	l_1	l_2	*h*	
16	30	78	40	52	18	4	0.14
20	35	96	50	64	22	5	0.25
24	40	96	50	65	21	5	0.36
30	46	112	60	75	35	6	0.65
36	55	132	70	90	28	7	1.10
42	60	145	80	103	36	8	1.68
48	70	170	95	118	32	10	2.60
56	80	185	105	129	36	10	3.85
64	90	210	120	146	40	12	5.80
76	100	235	138	172	39	12	9.00
90	120	260	155	191	35	12	14.0
100	140	295	175	217	48	15	14.7
110	150	320	190	235	55	15	18.6
120	160	365	210	266	59	20	22.0

76 mm are recommended to have welded handles made of steel rod 8-10 mm in diameter.

Before carrying or tilting materials with the use of pins, the slinger is to make sure visually that the pins correspond to the size stamped on them, moreover, check the pins for absence of bends, cuts or dents.

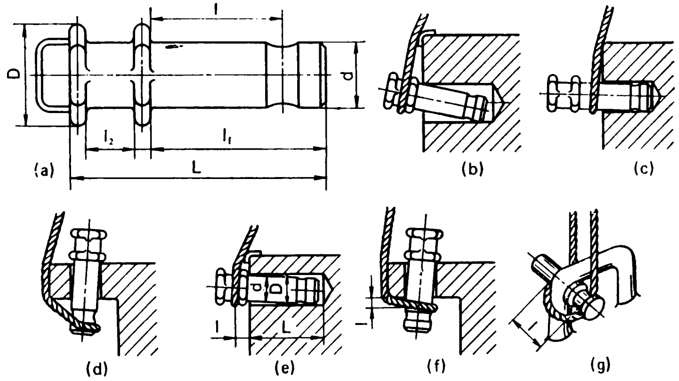


Fig. 20. Lifting pins:
a—lifting pin construction; *b* through *d*—incorrect installation of pins and slinging; *e* through *g*—correct installation of pins for slinging

When selecting the pins for holes in the parts to be handled, refer to Table 6 taking into account their load-

Table 6. Diameter of Holes for Pins, mm

Pin diameter, d_1	Hole diameter, d	Hole depth, L	Pin diameter, d_1	Hole diameter, d	Hole depth, L
16	17/-	55	56	60/62	130
20	22/-	65	64	68/70	150
24	26/-	68	76	80/82	175
30	32/-	78	90	95/98	195
36	39/41	95	100	105/108	220
42	45/47	105	110	115/118	240
48	52/53	120	120	125/128	270

Note. The numerator shows the diameter of a machined hole and the denominator shows the diameter of a cast hole.

Table 7. Lifting Capacity of Pins (Fig. 20)

Pin diameter, mm	Position of pins in the article		
	(*e*)	(*f*)	(*g*)
16	25/130	18/180	35/360
20	30/210	20/310	40/620
24	25/430	25/430	50/870
30	30/720	30/850	55/1500
36	35/1000	30/1200	60/2400
42	40/1400	30/1900	70/3300
48	50/1700	35/2500	85/4900
56	55/2500	40/3500	95/5800
64	60/3400	40/5100	110/7500
76	75/4700	45/7700	130/10600
90	85/6700	48/11900	140/16400
100	95/8300	50/16000	150/21000
110	100/10500	50/20900	175/23800
120	110/12300	55/24700	190/28500

Note. The numerator shows l in mm and the denominator shows tolerable lifting capacity P, kg.

carrying capacity given in Table 7. The angle of obliquity of the pin in the hole must not exceed 10-12°, otherwise the loaded pin may slip out of the hole.

While slinging the parts in the vertical position, it is strictly prohibited to insert pins into the holes with their heads down or to use pins without shoulders. The pins operating in the horizontal position are to be inserted all the way in until the shoulder rests against the hole edge. The depth of blind holes must not be less than that indicated in Table 6. If the hole depth is not sufficient, it is impossible to use pins. While slinging by the pins located vertically, the sling must be attached as close to the item as possible to reduce the bending moment.

It is strictly prohibited to hoist the item if the sling is beyond the fixing neck of the pin or if the article is secured not by the adequate lifting pin but by any other improvised subject.

Review Questions

1. What is the construction of a tongs-type grab?
2. What is the construction of an eccentric clamp?
3. What are the rules of material hoisting with the use of lifting pins?

Chapter IV

Detachable Materials Handling Attachments

4.1. Purpose, Design and Classification of Materials Handling Attachments

Materials handling attachments are designed for gripping materials and for securing them to a hook of the hoisting machine with the view of lifting, moving and stacking them for storage.

Materials handling attachments are usually detachable (Table 8) and comprise material-gripping members or devices, control rods or conveying ropes and securing members for connecting them to material-gripping members of hoisting machines.

The simplest lifting appliances are flexible and rigid slings designed for gripping the materials by special devices (eyebolts, hooks, loops, trunnions, etc.).

The multi-purpose lifting appliances are endless or single-leg slings built-up of chains or steel ropes (in some cases ropes of organic materials are used) which are designed to grip the materials by binding.

Specialized lifting appliances include various mechanized and automated attachments such as clamshell, tongs-type grabs and eccentric grips, electromagnetic and vacuum devices, etc. Specialized attachments are adapted for catching particular materials whose parameters—weight, configuration, overall dimensions, rigidity—may vary greatly, therefore the structural embodiment of lifting attachments is hard to standardize. Lifting attachments designed for special purposes make it possible to use them with highest efficiency and productivity. However,

Table 8. Classification of Crane Below-the-Hook Attachments

Classification characteristics	Attachment			
	Clamshell	Sling-type, claw-type container-handling	Tongs-, friction-, wedge-type, eccentric	Vacuum, electromagnetic, magnetic
Material	Bulk	Packaged-and-unit, long-cut, timber	Packaged-and-unit, timber	Long-cut, sheets, tubes and various magnetic materials
Method of gripping	Scooping	Supporting	Gripping	Attracting
Movement	Vertical	Vertical and horizontal	Vertical and horizontal, rotary about vertical axis	
Drive of the gripping attachment	Rope-type, electromechanical, hydraulic, pneumatic	Manual, electromechanical, hydraulic, pneumatic		Pneumatic and vacuum, electric, magnetic
Load gripping and release control	Remote, automatic	Manual, remote, semiautomatic, automatic		Remote, automatic

Note. Suspension of the materials handling attachments from the crane may be rigid or flexible.

most spread are multi-purpose tools: slings, hooks, load beams, various rings, rockers, etc. These tools allow to handle wide range of products of different configuration. They are also favoured for light weight and rapid replacement for the tool of another type.

Multi-purpose tools are also used for designing specialized materials handling attachments which can be divided into several groups.

The handling attachments for unit materials: tongs-type grabs and lever grips are used for moving barrels, rolls, boxes, sheet materials, etc. *Electromagnetic attachments* (lifting magnets) are employed for carrying the articles made of magnetic materials. Vacuum attachments (vacuum lifters) are designed to handle flat and curvilinear (with a great radius of curvature) articles having a smooth surface. *Tilting gear* used primarily to handle cylindrical materials (rolls, drums, barrels, etc.) turn over an item from the vertical position into the horizontal one and vice versa. *Fork lifts* and attachments with rotatable claws are used to transport boxes, piles of metal articles, sheet metal, etc. A special group is constituted by *attachments for materials handling provided with gripping elements*, i.e. those with a shaped head having a cylindrical groove, shoulder and special holes. These attachments are compact and are suitable for use in a limited space. Sometimes, they fulfil additional functions, in particular they can be used to press out the parts in repair shops, dismount the assemblies of machines and mechanisms.

Among *special-purpose grabs for containers* most widely spread in this country are driveless semiautomatic and automatic grabs for medium-weight containers. In semiautomatic grabs a container is slinged by hand and released automatically when the container is placed on the support. Automatic and driven grabs need no additional servicing: one operator of the hoisting machine handles containers with an automatic grab. However, due to acceleration of load handling operations such devices must be provided with mechanisms which precisely guide the attachment to the container. At present the industry in the Soviet Union produces specialised container cranes complete with automatic attachments for handling the containers weighing 10, 20, 30 tonnes.

Handling attachments for bulk materials include clamshells and clamshell mechanisms. Double-door excavator buckets and conveying vessels are often considered to belong to this group. However, they cannot be referred to as material gripping devices since they cannot scoop the materials. *Materials handling attachments* of loaders are designed to handle packaged materials (fork lifts, tongs, etc.).

By the method of control distinction is made between handling attachments with manual control, automatic control and remote control. According to the method of slewing they fall into freely slewable attachments (which easily slew together with the hook about its suspension) and forced slewable ones (slewed by special mechanism) controlled by the crane operator. To move and control pickup and gripping attachments, use is made of electric, hydraulic and pneumatic drives. Some simple attachments employ a manual drive (such as in eccentric grips).

A hoisting crane of a standard embodiment with a hook is provided with multi-purpose rope slings. A hoisting crane of a special embodiment is provided with special-purpose attachments for carrying the ladles with molten metal, hot ingots, etc. (see Table 8).

Review Questions

1. What kinds of materials handling attachments do you know?
2. In what groups are materials handling attachments divided?
3. What is the classification of general-purpose materials handling attachments?
4. How are materials handling attachments classed as to the methods of gripping?
5. What is the classification of materials handling attachments with reference to the method of their control?

4.2. Slings

Slings are the length of ropes or chains connected to form a loop or provided with business-end tools which are used for binding, fastening the material and suspending it from a hoisting mechanism and insure quick, convenient, reliable and safe securing of the load.

Slings of hemp and synthetic ropes are employed for slinging the items having a smooth machined surface, of not more than 1.5 tonnes in weight (ground and polished wooden items, light-weight materials). Such slings are recommended to be used with thimbles only avoiding application of metal business-end tools since they quickly abrade the ropes. In hot shops such slings find no use.

Slings built up of steel ropes are strong and durable, fail gradually so that it is easy to determine the degree of their failure but they are prone to damage at sharp bends and against sharp edges. In repeated loading the ropes are multiply bent, the wires break and the ropes are rejected.

In hot shops of machine-building works, particularly in casting shops, the slings of steel ropes are of limited use since an organic core of the rope rapidly burns out and the wires deprived of lubrication wear out quickly. Splicing or tying of sling ropes are not allowed.

Chain slings as well as steel rope slings can be used for lifting and movement of any materials in all production processes. The advantage of chain slings over steel rope slings is that they are more flexible, suitable for lifting parts and assemblies having sharp edges without any spacers, can be employed at high temperature, are well placeable onto the load and well removable therefrom which is very important in handling hot metal. But chain slings have a number of disadvantages: they are heavy, do not withstand sharp dynamic loads and can unexpectedly fail since the faults of these chains are difficult to detect. The disadvantages limit their application especially for lifting heavy and critical items in places where there are many people and equipment.

The experience has shown that common reasons for chain sling failure are their wrong use, overloading due to wrong marking or lifting dead loads, operators' carelessness, employment of worn-out slings. Slings whose links or gripping members are worn out by more than 10% in diameter of chain steel, and those having more than 30% of worn-out links or rejected due to other reasons cannot be further employed.

At present use is made of the following types of slings: rope slings, chain slings, multi-purpose rope slings, multi-purpose chain slings. By the number of legs, slings are divided into one-leg slings, two-leg slings, three-leg slings, four-leg slings and multi-purpose ones (Fig. 21). The number of sling legs which are used to suspend the load is selected depending on the weight, dimensions and configuration of the item.

Multi-purpose slings are made of three types: simplified slings, light-duty slings and endless slings (ring-type slings). A simplified sling is a length of a rope whose ends are prevented from untwisting: for hemp slings this is made with the help of hemp strands, for steel ropes this is done with the aid of annealed wire or by welding. Such slings are used to perform auxiliary operations, repair, mounting and dismounting operations. Materials are slung with the help of simplified slings by tying knots and loops.

A light-duty two-loop multi-purpose sling is a piece of a rope plaited from both ends into loops with thimbles or having one loop and the dead end with a seizing on. While catching the material it readily passes through the holes in items, loops, eyes, rings, ears, etc. forming several legs which increase its load-lifting capacity. A two-loop sling may serve as a component part of many complicated and specialized load handling attachments. In this case the sling loops are secured with thimbles which prevent it from rapid wear-out and sharp bending.

An endless (ring-type) multi-purpose sling is a closed ring-type piece of a rope or chain of required length. It can be made of steel ropes, chains, hemp and synthetic ropes. A multi-purpose sling as well as a two-loop one is employed for slinging various items. Depending on configuration and weight of the load it can use two, four and sometimes eight legs which is very important for conveying very heavy items. The item is bound by an endless sling using, as a rule, a builder's loop which insures strength and reliability of slinging. Under load the multi-purpose sling does not untwist in contrast to other rope slings, extends insignificantly, therefore its service life is longer.

A one-loop one-leg sling has a loop at one end and a hook, snap book, cramp or any other business-end tool at

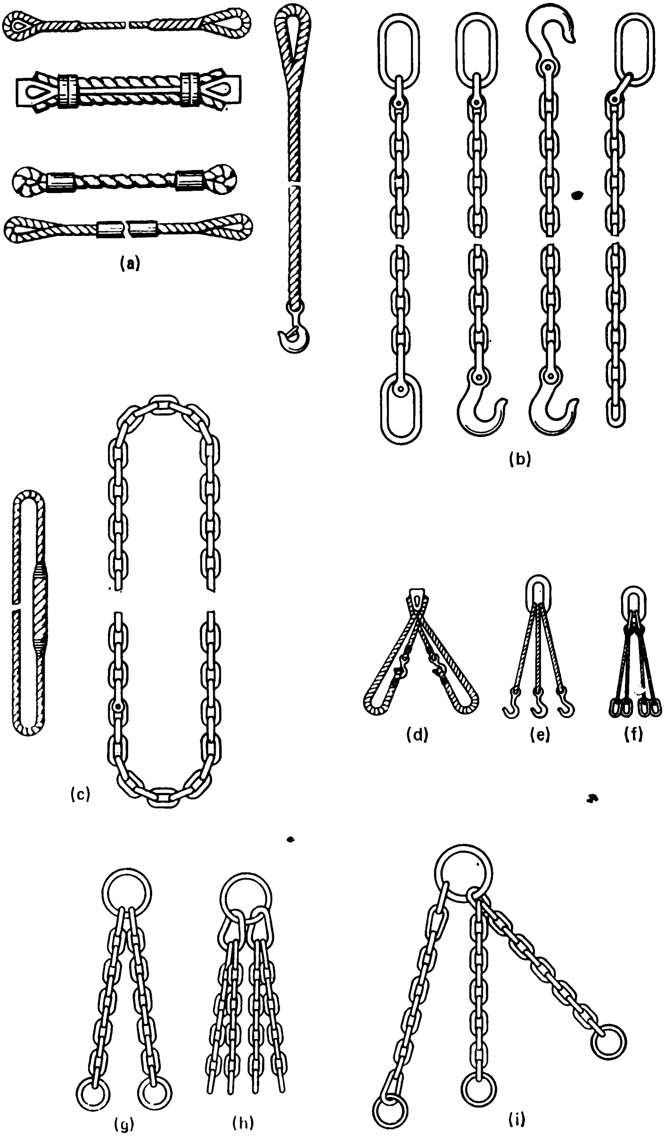


Fig. 21. Slings:
a—one-leg rope slings; *b*—one-leg chain slings; *c*—multi-purpose (endless) rope and chain slings; *d*—two-leg rope sling; *e*—three-leg rope sling; *f*—four-leg rope sling; *g*—two-leg chain sling; *h*—four-leg chain sling; *i*—three-leg chain sling

the other. Such a sling is used for movement of materials having mounting loops, eyes, hooks and other facilities.

Under maximum load the one-leg sling can untwist therefore it should be made of a regular-lay rope.

A combined sling consists of the elements of a steel rope and a chain. Loops and end portions of the sling are made of steel rope, while the middle portion of the sling as the portion prone to intensive abrasion is fabricated of a chain whose load-carrying capacity is 15-20% higher than that of the rope. Combined slings are manufactured to withstand a load up to 6 tonnes. They possess all the advantages of chain slings, moreover, they are more durable and more reliable. Heavy connecting rings necessary for chain slings are replaced by light and strong rope loops. Since the rope section of the sling has smaller load-carrying capacity, it is worn out earlier as if signalling that the sling is unsuitable for work. A rope section of the sling also serves as a shock absorber under dynamic loads cushioning jerks and preventing breaks. A rope-chain combination sling is designed to move welded and cast items with sharp edges and ribs, rails, bearing housings, metal structures, etc.

A multi-leg sling consists of several legs interconnected by a common steel ring. It is intended to hook an item by two, three or four points. This kind of slings is widely spread in slinging heavy-weight loads, tanks, and the like provided with ears, loops, stirrups, trunnions, etc.

While using multi-leg slings it is necessary to see that the load is uniformly distributed among its legs.

Depending on the material to be lifted the slings are provided with special grips: rockers, rings, hooks, lifting crams, etc.

The construction of slings and materials handling attachments must exclude every possibility of an accidental detachment of the load. While marking multi-leg slings, it is necessary to indicate the load-lifting capacity of the entire sling and of its separate sections, legs. It helps slingers to correctly choose a sling and to more exactly calculate the efforts for a leg and for the entire sling when lifting the load by several legs.

All the slings and handling attachments in stock are to be provided with tags with a clear indication of the registration No., load-lifting capacity and the date of the following test.

To move long-cut materials and cumbersome items use is often made of *load beams*.

Review Questions

1. What kinds of slings are used in industry?
2. What is the application of multi-purpose slings?
3. What is the construction of multi-leg slings?

4.3. Designing of Sling-type Materials Handling Attachments

The fabrication of a sling can be divided into two main periods: preparatory and assembly.

During the preparatory step a foreman or mechanic develops technical requirements and receives ready working drawings. When designing materials handling attachments, it is necessary to take into account the scope of work: for small batches of material the multi-purpose slings are recommended; for articles of series or mass production the special-purpose slings are to be used. Slings intended for hot shops are better to be made of chains and for assembly shops and construction sites steel rope slings are advisable. While finding the diameter of a rope or sling chain one should take into consideration the weight of the material, the number of sling legs, the angle between the legs, and the safety factor which must be not less than 6 for steel ropes, not less than 8 for hemp ropes and not less than 5 for chains.

The business-end tool of a sling is selected according to the place of attachment and method of load binding; for flanged items the cramps or pins are to be taken, for articles with ears the hooks are preferable. To prevent steel ropes from sharp bending, to reduce their abrasion at the places of connection to the rings and attachments, thimbles are to be mounted into the loops. Sometimes technological conditions make it impossible or undesirable to install thimbles in slings having business-end tools (hooks, snap hooks, cramps rockers, etc.) since their loops become larger and this creates difficulties in work and complicates connection of the attachment. In this case the ropes are plaited right into the holes of the attachment without any thimbles. However, one must take into consideration the tendency of steel ropes especially those having soft cores to deformation at the places of bending. To prevent the rope from deformation and make it operate normally, the diameter of the attachment hole to which the sling is plaited in must be 1.25 of the rope diameter, the minimum radius of the bending in the rope and in the attachments be not less than 0.75 of the rope diameter, and the sling loop length be not less than the length of the loop plaited for a thimble. The thickness of the end gripping tool is calculated or selected structurally. It is allowed to be adjusted to the assigned thickness by welding additional washers. To avoid internal stresses the washers are to be welded with a short intermittent seam in 4-5 points. To form a rounding, the hole at its beginning is reamed out at an angle of 90° to the depth of a chamfer and then sharp edges are rounded to fit the radius. The hole is to be rounded only along the section of a sling loop working portion. The mating surface of the gripping facility and the rope must be machined with a very high quality.

If the surface for splicing is properly selected and machined, there is no need to use thimbles since at the section where the loop is connected to the load gripping device or to any other business-end tool the rope takes a form close to an ellipse under load, does not deform, and has a 12-16 fold safety factor working for two legs. Slings without thimbles are cheaper, lighter, more convenient in use and simpler in fabrication.

Sling loops are formed in several ways: securing by clips, splicing, etc. A method of steel rope securing by clips is simple and can be accomplished by any more or less skillful worker, but it is seldom used since slings with such clips are not convenient in operation. In load gripping attachments clips are used in the following cases: for forming loops when fabricating provisional slings; for slings working without material binding and which are not intended for passing through holes; for slings with a very small distance between loops making it impossible to splice them; for fastening the ropes to a load beam; for hoisting ropes used in load-lifting mechanisms.

Clips are of different construction (Fig. 22). A simplest L-shaped clip comprises two bent bolts. To form a loop, a dead end of the rope together with the live end are inserted between the bolts and tightened with nuts. A U-shaped clip comprises a collar with a nut and a strip with a prismatic slot. It is simple in fabrication and secures the rope well. A clip with a spiked body includes a collar with a nut, a four-spike cast body, and a stop strip which prevents the nuts from accidental unscrewing. It can secure the rope ends well but is difficult to fabricate and therefore is seldom used.

A reinforced clip has a body with three spheric projections spaced at 60°. The strands of the rope loop dead end are placed into the projections on the body and are pressed by the collar. While installing the clip on a sling the collar nuts are tightened gradually one by one so as to prevent the thread from stripping. In any case the collar should be fixed by two nuts as a minimum. Depending on the rope diameter each loop is to be secured by 3-5 clips. The distance between them must be equal to six diameters of the rope.

When developing slinging facilities one should always take into consideration particular features of each sling. A one-loop one-leg sling provided with one business-end tool is prone to untwisting if manufactured of long-lay rope. Therefore, if a regular-lay rope is not available, it is advisable to attach grips to a general-purpose (endless) sling employing two legs. In such slings the ropes may be of a smaller diameter and the slings themselves become more convenient in work, the ropes do not untwist under load, are less expansible and more durable. Nevertheless, ring-type (endless) slings have some disadvantages, if they are long: the legs under load may twist together and spin the item (load) or the hook block which is fraught with accidents. To prevent the sling from twisting together, special spacers are placed upon it.

The rope sling ends are terminated by swaged terminals, wedge-type sockets, and by splicing.

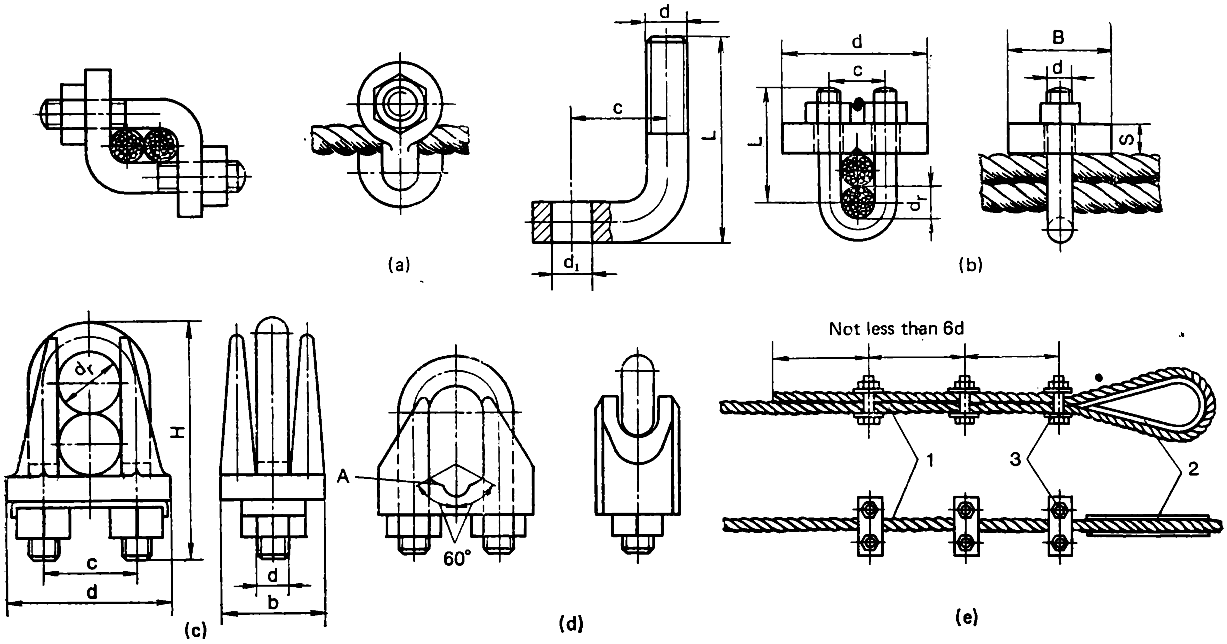


Fig. 22. Clips:
a—L-shaped clip; *b*—U-shaped clip with a strip; *c*—clip with a spiked body; *d*—reinforced clip; *e*—sling loop formed by clips and thimble; *1*—rope; *2*—thimble; *3*—clips

The swaged terminal (Fig. 23) comprises an aluminium terminal (sleeve) squeezed about the legs of the ropes being connected which stick together and engage with the terminal metal to form a homogeneous body. The fabrication procedure for this connection is the following: an oval aluminium terminal is fitted on the rope leg forming a loop about the thimble in such a way that the rope tail end protrudes out of the swaged terminal by not less than 2 mm. Then the assembly is squeezed until the terminal is round in cross section. There are two methods of squeezing an aluminium terminal: in an open die and in a closed die.

A wedge-type socket is designed for terminating the rope ends with a thimble and without it. The socket is actually a cylindrical sleeve inside which an insert is put between the rope strands.

An oval steel socket is mounted on the rope leg forming a loop about the thimble. To tighten the rope about the thimble, the socket together with the tail portion of the rope is moved to the loop obtained. In doing so, see to it that when the thimble is tightened by the loop the tail portion (leg) protrudes by not less than 20 mm out of the socket from the side opposite to the thimble. An insert is knocked into the middle of the socket between the

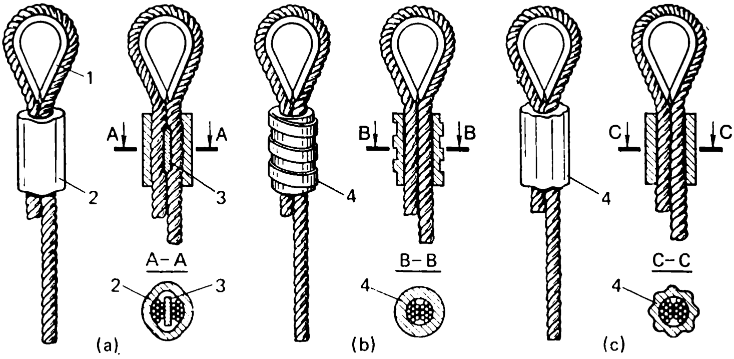


Fig. 23. Application of terminals to form a loop: *a*—loop formation by squeezing a terminal with an insert; *b*—loop formation by crimping machine over the circumference without an insert; *c*—loop formation by broaching without an insert; *1*—thimble; *2*—terminal with an insert; *3*—wedge insert; *4*—terminal without an insert

rope legs. Then the thimble with the loop is secured in the vice and the socket is knocked at its butt end opposite to the thimble until the rope is tightly secured about the thimble. This done, the assembly is squeezed about.

When designing chain slings one should take into account that their assembly is more complicated and requires electric arc or gas welding therefore it must be accomplished by highly skilled specialists according to a preliminarily worked out technology. In selecting the terminal rings, it is necessary to take into consideration not only the load-carrying capacity of the sling and the size of its elements, but also the crane hooks from which these rings are to be suspended.

Review Questions

1. What does the preparatory period of sling fabrication consist of?
2. How are the sling rope ends secured?
3. What are the methods of securing sling rope loops?

4.4. Assembly and Fabrication of Slings

A sling is usually manufactured by locksmiths, turners, milling machine operators and other specialists. A sling assembly consists in fabrication of loops and splice joints (for rope splicing and joining). Splicing of slings—the main operation—is carried out by a skillful worker.

Fabrication of a sling begins with a preparation of a rope length of adequate diameter and quality. The rope length includes a sling length and a section necessary for forming loops, splicing and production allowance. To prevent the rope from untwisting, the places of cutting and the base of unlaying are tied with seizings which are put at a distance of 1-4 diameters of the rope from the place of cutting. To preclude the strand wires from untwisting and injuring operator's hands during splicing, their ends are to be covered with a scotch.

Seizings for steel ropes are made of a soft wire or of a seizing cable. By the method of application, seizings are divided into simple and self-tightening ones. A simple seizing is applied to the rope at some distance from its ends (Fig. 24*a*). One end of the wire is placed along the rope in the form of a loop and then the rope is wound around with 10-15 bights (in temporary seizings the number of bights is 6-10). The remaining end is passed into the loop and using it the bights are pulled under the seizing. The free ends are cut away and the seizing is ready.

A self-tightening seizing (Fig. 24*b*) is applied to the ends of the ropes and their strands. One of the wire ends is placed between the rope strands and is wound around with 5-6 bights towards the rope end. Then the second end of the wire is placed along the rope between its strands and is wound by the bights of the loop formed. Then the free end of the loop is pulled under the bights and cut off. If the self-tightening seizing is applied not to the end of the rope but to its middle portion the last 5-6 turns are loosely wound about a spacer placed along the rope. The bights being laid about, the free end of the wire is pulled through. The spacer is removed, the bights are tightened one by one and the free end is pulled under them in the same way as when the seizing is applied to the rope end.

A sling is spliced by means of a special device on which the rope secured vertically is free to rotate. Somewhat below the mark of the section intended for loop formation the rope is pierced with a brad-awl having oval grooves on its sides thus separating a strand from the rope; the awl is turned through 90° as a result of which a hole is made into which one of the strands of untwisted rope is passed until it stops against a cut-away core. Then the awl is turned back and pulled from under the strand and the strand of the rope dead end is pressed by the strand of the untwisted rope interweaving with it.

While preparing ropes for joining (Fig. 24*c*) temporary seizings *11* are applied to their end strands. After the seizings have been applied the rope ends are untwisted into strands *9* and the place of the untwisted end is fastened with a seizing *10*. While joining the ropes the strands are first placed in pairs (II) so that a pair of strands of one rope turns to be between the strands of the other rope. Then the strands of the rope are separated one by one (III) so that each strand of one rope is between the strands of the other rope.

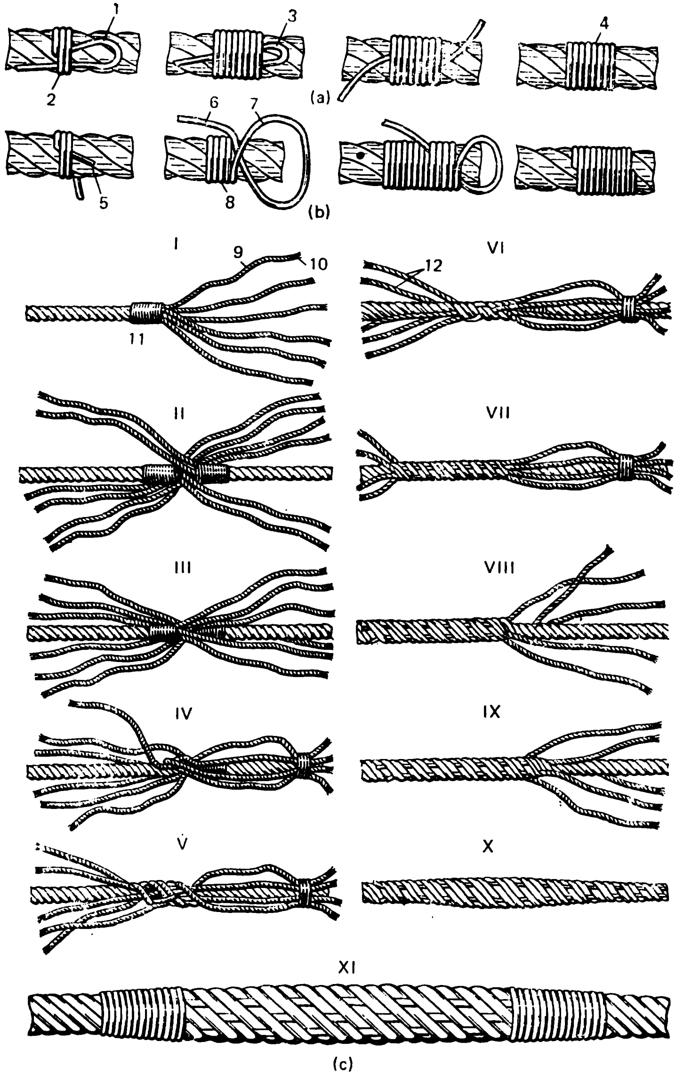


Fig. 24. Application of seizings and splicing of ropes: *a*—simple seizing; *b*—self-tightening seizing; *c*—short splicing; *1*—loop; *2*—bight; *3*—end of binding wire; *4*—seizing; *5* and *6*—the first and the second ends of the self-tightening seizing; *7*—loop; *8*—bight; *9*—strand; *10*—strand seizing; *11*—temporary seizing; *12*—half-strands

When joining steel ropes the strands are tucked successively according to the following pattern—every other one under two—(IV), that is each unlaid strand is tucked over the neighbouring one and under the following two strands, thereby the unlaid strands are always tucked against the lay of the rope. Each unlaid strand is tucked under the laid strands of the second rope two times (V), then half of the wires is removed from the strand (VI) and the strands *12* having half of the wires are tucked for the third time. Before the fourth tucking (the last one) only a quarter of wires is left in a strand. This is done to diminish the splice thickness to its end (VII) in order to distribute the stresses arising at the ends of the splicing which may be the reason for the rope break.

After four tuckings have been accomplished the ends of the strands are cut off, the strands of the second rope are untied and its strands are started to tuck (VIII). Here two tuckings are made for the strands having complete number of wires, then the strands are undercut twice (IX) to accomplish the third and the fourth tuckings.

While tucking, after each step the strands are beaten with a wooden hammer so that the strands better fit each other and after the tucking is completed the strands are stretched, the splicing is beaten once more with a wooden hammer, and the strands are cut off. The splicing (X) has many wire ends sticking out which make it unsuitable for use (there is a possibility to injure people working with the rope). Therefore, when splicing steel ropes it is obligatory to apply seizings *10* (XI) of a soft wire or a seizing rope to the splicing ends so that the seizing completely covers the portions of the strands with cut and protruding wires.

To simplify the work, three strands can be tucked three times and the other three ones are tucked four times which tapers the splicing to its ends.

Steel ropes as well as hemp ropes can be provided with simple loops and loops with thimbles.

A simple loop (Fig. 25) is also made after the rope is prepared for termination. It consists in applying a seizing to a rope, seizings to the strands and untwisting the rope into strands. The end of the rope is placed so that it forms a loop (I), dead strands are arranged by three on

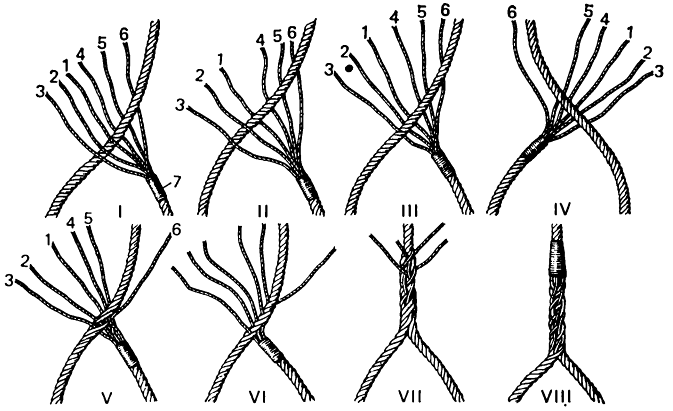


Fig. 25. Side splicing of steel ropes:
I through VIII—positions of splicing; *1* through *6*—Nos. of the rope strands; *7*—seizing

each side (in the figure the strands are numbered in the order of the tucking from 1 to 6).

The first strand is tucked under three strands from right to left against its lay (II), the second strand is tucked under two strands of the rope, and the third strand is tucked under one strand (III). Then the loop is turned over and the fourth strand is tucked under two strands and the fifth strand, under one strand (IV). The strands are tightened so that the seizing rests against the laid end, the loop is turned over again and the sixth strand is tucked under one strand of the rope but not against the lay of the rope but in the direction of lay (V). This concludes the first tucking step which is to be checked for correctness. If the tucking is correct the unlaid strands must be located every other strand of the rope. Subsequent tucking of the unlaid strands is accomplished against the rope lay (from right to left) according to the following pattern: every other one under two (VI). After each tucking procedure the strands are tightened by hand or by a hoist if the rope is very thick with subsequent beating with a wooden hammer.

In order to reduce the rope thickness at the joint, it is necessary to cut off every other unlaid strand after the third tucking and accomplish the fourth tucking (VII) with the use of the three remaining strands. Thereafter the remaining strands are cut off and the places of cutting are covered with a seizing of a soft wire or a seizing rope (VIII).

A loop with a thimble is made in a rigging vice and, if no vice is available, by fitting the rope tightly in the thimble notch by hand which is a labour consuming operation if the rope is thick. In case of hand work 3-4 temporary seizings are applied in succession to keep the rope in the thimble notch. After the rope with a thimble is secured in the vice or they are clipped together, the end of the rope is untwisted into strands in the same way as fabricating a simple loop and the strands are spliced into the rope in a similar order.

A loop is manufactured by means of rope clips in the cases when the slings with loops are not liable to bending (such as for permanent guy ropes, and also for attaching the loads). In the clips for joining steel ropes the U-member and the strip are connected and tightened by means of nuts with washers.

The size of the clips must correspond to the rope thickness. They are selected in accordance with the symbols stamped on the strips.

While making loops by means of clips a rigging vice is also used for tightening the loop. The clip is located with the plate on the live end of the rope at a distance of not less than six diameters of the rope from each other. The number of clips depends on the rope thickness. If the rope diameter is 16, 16-27, 27-37 and more than 37 mm, the number of installed clips must be 3, 4, 5, and 6, respectively.

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4.5. Sling-type Materials Handling Attachments with Remote and Automatic Control

Remote and automatic hooking and unhooking of the slings increase the efficiency of crane equipment and labour productivity of riggers and slingers, and insure safety of slinging operations. In simple attachments of this kind the hook is rotated by means of a lever or a line when the sling is slackened.

General-purpose materials handling attachment with remotely controlled unhooking (Fig. 26*a*) comprises a suspension, pulley blocks attached to it by means of rings, sling legs and balancing ropes. Dead ends of the slings are provided with hoisting hooks with the casings closing the hook mouth and the links which rotate the hook. The suspension structure makes it possible to take up one-sided loads through its rotation about the mounting crane hook in the vertical plane and the rings insure its revolution about the vertical axis of the casing through 120°.

The attachment capacity is 10 tonnes and the weight is 195 kg.

An attachment for slinging and remote unslinging of building structures, production equipment and other materials (Fig. 26*b*) consists of a casing, a special hook mounted in the casing on the pin of the handle with a retainer, an extension spring, a spreading spring resting on the disks and a guide rod with a fork. The bracket of the lever which is rigidly connected to the hook is provided with the holes for securing the lever. One end of the handle made as a fork overlaps the lever while the other end is connected through a ring to the unslinging line. The handle is free to revolve on the lever about the hole axis through 135° thereby the retainer comes into engagement with any of the four grooves on the lever and reliably locks the handle in the position. Provided in the upper part of the attachment is a pin to couple the attachment with the sling of the load-lifting mechanism.

The mouth is blocked with a hook nose and is normally locked under the action of the spring. It gets open upon handle rotation by hand or by pulling the unslinging line. The bail on the casing insures the most favourable angle between the unslinging line and the handle in the horizontal position.

The load is slinged by engaging the mounting loops directly with a hook or by means of additional ring slings by making a slip knot. Before lifting the load the handle is positioned so that in case of remote opening of the attachment the angle between the tightened unslinging line and the handle reaches 90°. If this condition cannot be observed the handle is set to the horizontal position and the unslinging line is passed through the bail. To

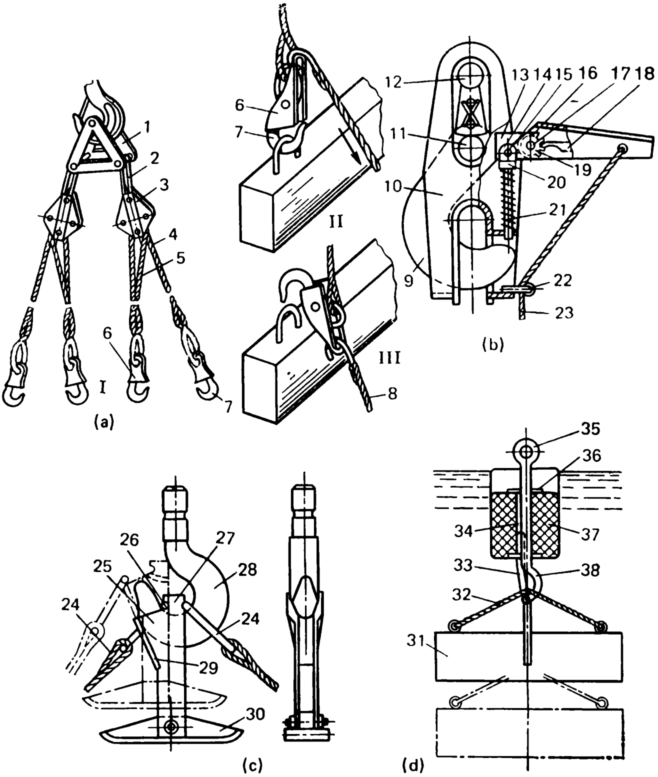


Fig. 26. Sling-type materials handling attachments with remote unhooking:
a—general-purpose sling attachment; *b*—ЗСП-3А handling attachment with remote unslinging; *c*—attachment for automatic release of the hook from the lifting sling loop; *d*—attachment for automatic underwater unslinging of load; I—general view; II—position of the hook in load catching; III—position of the hook in unslinging; *1*—suspension; *2*—yoke; *3*—pulley block; *4*—sling leg; *5*—balancing rope; *6*—hook casing; *7*—hoisting hook; *8*—guy rope; *9*—hook; *10*—casing; *11*—handle pin; *12*—pin; *13*—lever bracket; *14*—fork; *15*—hole for axle; *16*—handle; *17*—hole for retainer; *18*—extension spring; *19*—retainer; *20*—support disk; *21*—spreading spring; *22*—bail; *23*—unslinging line; *24*—attaching rings; *25*—stirrup plate; *26*—shaped stirrup; *27*—jumper; *28*—hook; *29*—inclined strap; *30*—foot; *31*—load; *32*—sling leg; *33*—lever; *34*—tube; *35*—eye; *36*—flange; *37*—float; *38*—stalk-like hook

change the position of the handle, it is pulled out until the retainer disengages from the groove on the hook lever, then the handle is placed in a required position and fixed.

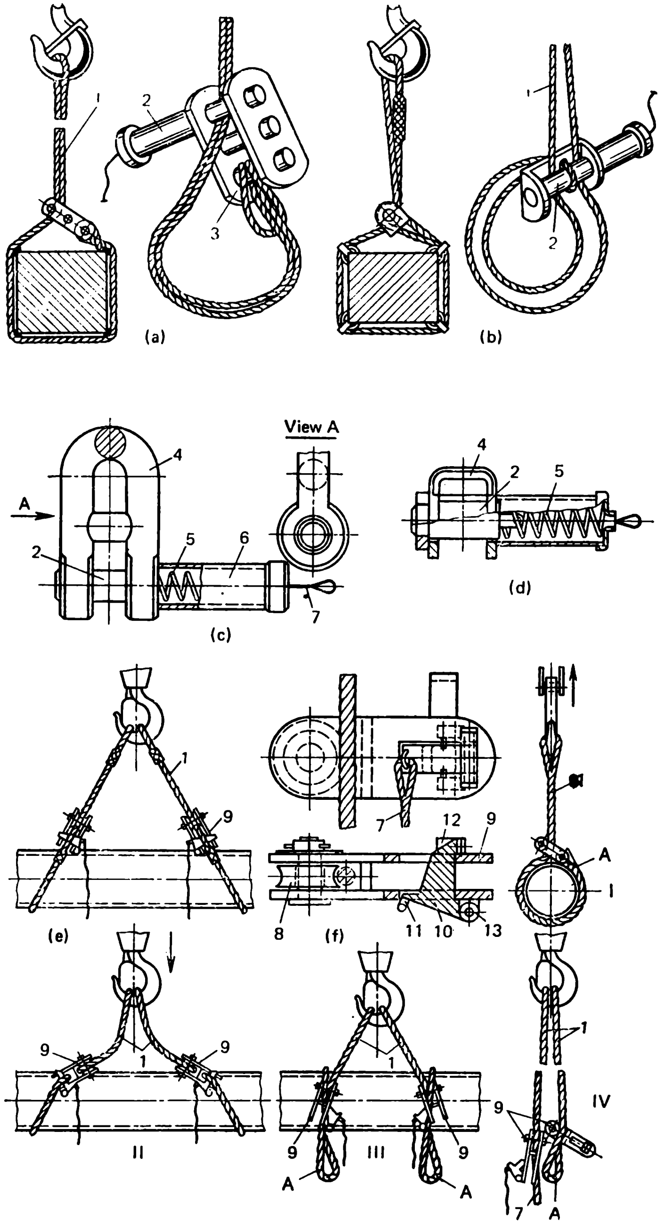
Remote unslinging is accomplished by pulling the unslinging line after the load is released from the hook. When there is no need in remote unslinging the handle can be brought to the lowermost position.

The lifting capacity of the attachment is 3 tonnes, the overall dimensions are 70 × 200 × 320 mm, the weight is 7.5 kg.

A device for automatic release of the hook from one end link of the hoisting sling loop when the load is released is mounted about a standard single hook. The device consists of two shaped stirrups connected in the upper portion by a jumper (Fig. 26*c*). The stirrup side plates follow the shape of the hook nose and are interconnected by an inclined strap over which the hook slides. The shaped stirrups, jumper and the straps form a casing which is provided with a foot at the bottom. The upper portion of the stirrup covers the hook mouth thus preventing the sling end links from falling out when in the working position. The stirrup side plate is used to drop the sling link off the hook. The hook is released of the hoisting sling loop only when the foot rests against the load. In this case the hook slips into the casing under gravity and the sling link is released from the hook. The dotted lines in Fig. 26*c* show interaction of the device parts at the moment the link is dropped off the hook. The lifting capacity of the device is 5.1 tonnes, the weight is 15.22 kg.

A slinging attachment has been developed for automatic slinging when the load is dipped into water. It has a hook (Fig. 26*d*) in the form of a stalk and a lever hinged to it. The stalk-like hook terminates in an eye. A float is freely fitted on the stalk and the lever. Mounted by means of flanges in the inner hole of the float is a tube. The stalk and the lever are connected to the load through a sling.

The attachment operates as follows. The load is secured to the attachment connected to the ship's lifting facility by an eyebolt, the slings are brought in about the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arm of the hook, the lever is turned up until it comes in contact with the stalk, thereafter the float is lowered down over the stalk and in this position the tube locks the lever in the closed position. The load lifted by the ship's load-lifting facility is dropped overboard and lowered into water. While sinking the float goes up over the stalk and releases the lever which under the action of the slings collapses down and releases the sling together with the load.

Pin-sling attachments (Fig. 27) comprise attachments in which a rope sling is used for gripping the load and a pin device (pin lock) operates as an auxiliary device for convenient unslinging of the load at a certain distance, say, at height. The lock is a frame which houses a shaft and a movable pin. The sling is secured in the pin device to the shaft and after the load to be lifted is slung it follows the pin and is suspended from the hook with a free loop (Fig. 27*a*). After the item is installed in its place and the sling is slackened, the pin is pulled out and the attachment is released.

In a simplified embodiment (Fig. 27*b*) the sling loop is passed through the hole in the frame and is fitted on the pin due to which the pin serves both as a shaft and as a pin device.

Pin locks may be of different configurations (Fig. 27*c*). The pin lock with a frame is made as a bail with a welded membrane. The pin is connected to a spring which holds it in the bail. To release the slings, the spring-loaded pin is pulled out of one side of the arc-shaped frame by a rope and after the rope is slackened the pin returns into the frame under the action of the spring.

Fig. 27. Pin-sling materials handling attachment:
a—attachment with a pin device separate from the capturing shaft; *b*—attachment with the capturing shaft and pin device combined; *c*—lock with a stirrup for sling capturing and a pullable pin; *d*—lock with a capturing shaft and pin device (lock) combined; *e*—attachment with an anchor lock for remote unslinging; *f*—lock for remote unslinging; I through IV—positions illustrating sling disconnection; *1*—sling; *2*—pin; *3*—capturing shaft; *4*—stirrup; *5*—spring; *6*—spring body; *7*—pulling line; *8*—guide-off roll; *9*—side plates; *10*—lever; *11*—ear; *12*—spring-loaded catch; *13*—lever axle

Use is also made of a similar pin device in which the pin is combined with a capturing shaft (Fig. 27*d*). Since the pin is under the effect of the remaining strains of the sling as well as a portion of the attachment weight, it is necessary to overcome during pulling the friction force arising between the sling, pin and the seat along which it moves. This force is quite great therefore it is difficult to pull the pin out.

In the pin device shown in Fig. 27*f* the line extraction is easier because the pin is provided with a twisted stem which interacts with a rotatable nut-drum about which the control line is wound. The line being tightened, the nut-drum rotates while the screw propels since its rotation is barred by a key entering the shaft groove. The device is used for lifting steel, ferro-concrete structures and production equipment.

In some devices (see Fig. 27) the rope can be pulled out under any spacial angle by means of a rotatable arrangement which is installed on the lock housing by means of ball bearings. A spring located in the housing keeps the movable pin closed. The line for unslinging is connected to the movable finger.

Also developed in the Soviet Union are sling-type attachments of different capacity in which the lock for remote unslinging of the load is provided with a guide-off roll and the arrangement for fixing the sling back leg comprises a rotatable double-arm lever connected to a remote control one (Fig. 27*e*). The advantage of such a sling-type load gripping facility resides in the fact that its rope does not rub against the housing during load slinging and this extends its service life. The materials handling facility is designed for slinging pipeline sections, big units, long structures (beams, trusses) mounted at a considerable height and tied with a builder's loop. To attach the structures, use is made of two-loop (light-duty) and general-purpose (ring-type) steel slings.

A hoisting sling comprises a sling proper and remotely controlled lock which is actually a housing built up of two side plates. Mounted on the axle inside the housing on one side is a guide-off roll, and on the other side is an arrangement for locking the reverse leg of the sling which is a rotatable double-arm lever with an eyelet connected to the line of the remote control.

One of the lock side plates mounts a spring-loaded catch and the other carries the lever axle which is located in the plane of the builder's loop.

To assemble the sling, the lock with the roll is removed from between the plates, the sling is passed between the side plates and the roll is mounted on its place.

The load to be lifted is embraced by the sling suspended by its loop from the crane hook, and rotating the double-arm lever clears the space between the side plates into which the loop *A* of the sling reverse leg is inserted. The double-arm lever is turned into the sling loop and side plates until it is fixed by the spring-loaded catch. Moving the hook upward tightens the sling about the load with a builder's loop. During sling tightening the roll rotates about the axle and insures uniform tightening of the sling without any jerks and reliable locking of the double-arm lever. After the load is installed and secured, the hook is lowered slackening the sling and the lock is released by pulling the line. After unslinging the lock hangs on the lower loop of the *A* sling. This done, the sling is ready for the following lift.

A slinging device having a 15 tonne capacity is outfitted with two rolls instead of one.

The greatest advantages over the above-discussed mechanisms are offered by *pin-sling mechanized attachments* having a remote control (by means of electromagnetic and pneumatic drives) of unslinging accomplished from the crane operator's cab. They insure safe work and accelerate mounting and slinging operations. The main types of pin-sling mechanized attachments used nowadays are shown in Fig. 28. A general procedure for materials slinging is schematized in Fig. 28*a*.

The 10-tonne attachments depicted in Fig. 28*b* and *c* are similar in design and differ only in the drive for pulling out the pin. The embodiment shown in Fig. 28*b* employs lever-pneumatic drive actuated by compressed air delivered at 0.3 MPa. A brake chamber of a truck is used as a pneumatic pusher. The attachment weighs 45 kg. In the design shown in Fig. 28*c* the drive is lever-electric one operable from a 36-V mains. A brake magnet

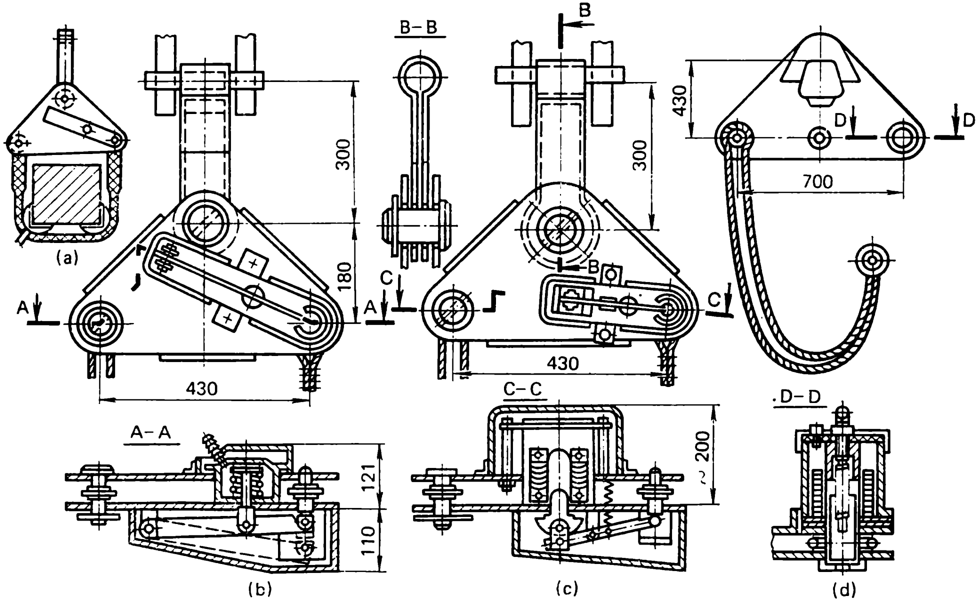

Fig. 28. Pin-sling mechanized handling attachments with remote control:
a—general view; *b*—attachment with lever-pneumatic drive; *c*—attachment with lever-electromagnetic drive; *d*—attachment with leverless electromagnetic drive

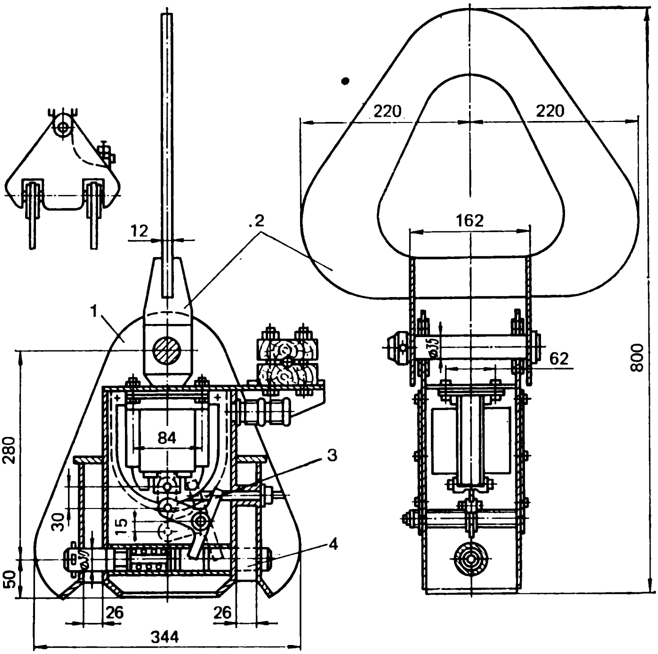

Fig. 29. Unified pin-sling load gripping attachment of 4-tonne capacity with remote control (lever-electromagnetic drive): *1*—housing; *2*—shackles; *3*—lever; *4*—handle

is used as a pusher. The attachment weighs 55 kg. An attachment with a leverless electromagnetic drive (Fig. 28*d*) has a 20-tonne capacity. The pin is normally closed by a spring.

The pin is pulled out by an electric magnet having an A.C. or D.C. supply.

Also developed are pin-sling materials handling attachments controlled by brake electric magnets. They differ from those discussed above in that the attachments allow to guide the pin better if the bushing is extended. Such attachments are designed for hoisting, conveying and mounting metal, prefabricated ferro-concrete structures weighing up to 16 tonnes. The drives for pulling in the pin employ electric magnets with a 127-V A.C. supply.

A load gripping attachment shown in Fig. 29 consists of a housing, shackle, magnetic drive, lever, handle, locking pin, electric wiring, and one-leg sling with thimbles. The housing is a welded structure of steel plates. The locking pin comprises a pin, cylinder, and spring.

While slinging the load the sling embraces the necessary element of the item and the free end of the sling is fitted on the extensible portion of the pin. In the open position the pin is held by the magnet and in the closed position, by the spring.

The item is unslung mechanically by the movable pin using a magnetic drive actuated from a push-button dashboard installed in the crane operator's cab or manually by the handle.

All the pin-sling materials gripping attachments provided with pneumatic and electromagnetic drives are controlled by the crane operator from the crane cab. To exclude the possibility of inadvertent actuation, the magnetic starter coil circuit has a switch connected in series with the starting push-button. The switch is to be thrown in before the push-button is depressed and turned off after the unslinging is over. The third conductor of the supply cable is designed for grounding. Its one end must be connected to the housing of the materials gripping attachment, while the other end, to the metal structures of the crane. If a load beam with two load gripping attachments is used, it is provided with a terminal box which receives the cables from both attachments.

Review Questions

1. What is the construction of the sling hook remote control?
2. What sling tools are provided with remote control?

Chapter V

Specialized Attachments, Manipulators[1] and Robots for Materials Handling

5.1. Supporting Blade-type Materials Handling Attachments

The working members of blade-type (fork) handling attachments are arranged right under the load or inserted into mounting loops, holes in the items or pallet upon which the material rests (Fig. 30).

By the method of inserting the blades (forks) under the load or its elements there may be attachments with fixed, horizontally and vertically turnable blades. There are also attachments in which the blades are made as rockers rotatable both about a horizontal and vertical axis. Depending on the purpose the supporting blade-type attachments may be of various designs. They are intended for lifting the materials arranged on the pallets. The blades are inserted into the clearance in the pallet until the center of gravity of the item lines up with the vertical of the suspension point to prevent the load from inadvertent slipping off the blades. Moreover, the attachments can be used for engaging the loads having cavities. In the first case the attachments are made with two blades or with greater number of blades when long articles are handled, thereby the blades are attached to a beam. The blades are advisable to be located so that the load-free blade is inclined forward towards the free end to facilitate its bringing into a slot of the item or between the pallets and its extraction therefrom, while the load-carrying blade is inclined backwards to insure stable positioning of the load on the blade.

To properly position the blades in the horizontal plane when bringing in an empty attachment and lifting a loaded one, the suspension point is to be shifted so that it is always under the center of gravity of the attachment. Different ways are used to balance the attachment.

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[1] According to Reference 2.

Pickups and supporting members are remote-controlled by electromagnetic, hydraulic, or pneumatic devices.

The control of crane blade-type attachments becomes simpler if the crane is provided with two hoisting mechanisms. That being the case the blades are hinged to a load beam suspended from the hook of the main hoisting mechanism and their walls are connected by a second light-weight load beam which is controlled by the second hoisting mechanism of a smaller capacity.

Crane load handling attachments with blades (forks) rotatable in the vertical plane are designed for reloading big piles or packaged unit materials on pallets or bundles

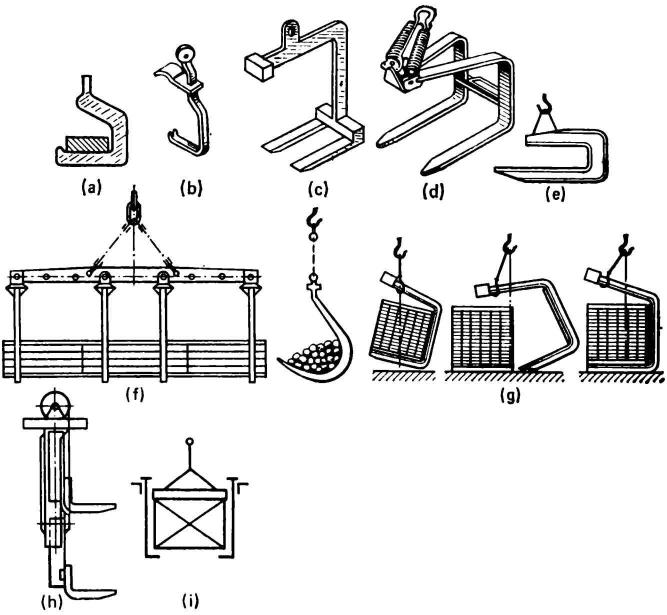


Fig. 30. Supporting blade-type materials handling attachments: *a* and *b*—single-blade attachments; *c* and *d*—double-blade attachments; *e*—attachments for heavy-weight loads (metal rolls); *f*—four-blade attachment on the load beam for long materials; *g*—attachment for loads on a pallet; *h*—fixed attachment rigidly fastened to the stacker; *i*—attachment with vertically rotatable blades symmetrically mounted on a frame

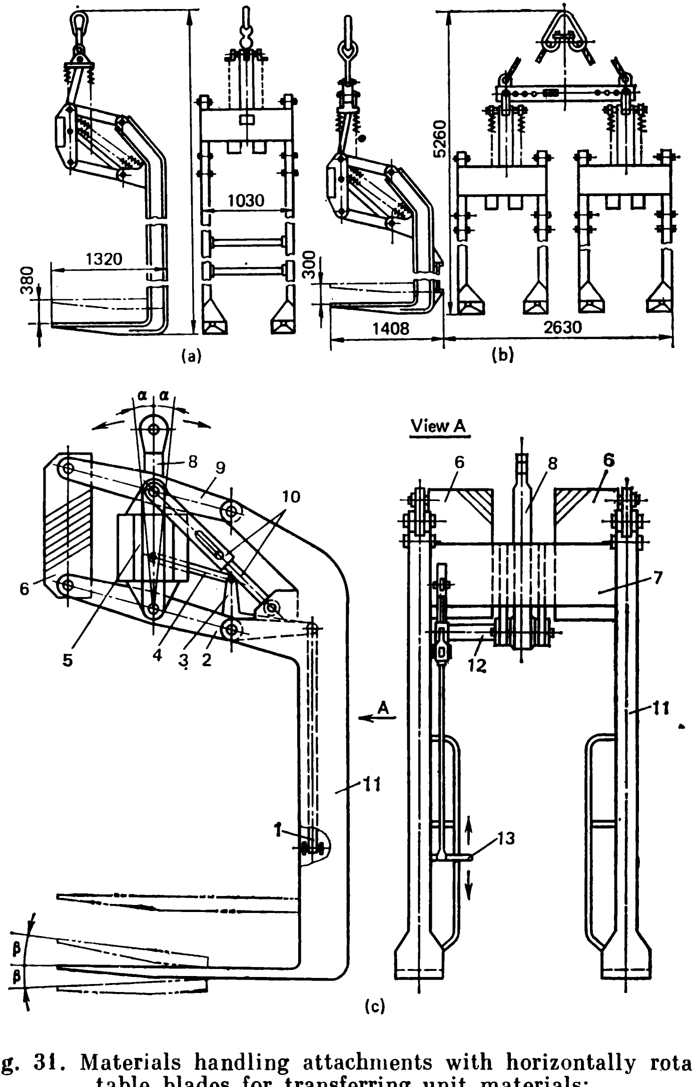


Fig. 31. Materials handling attachments with horizontally rotatable blades for transferring unit materials:
a—6.3-tonne attachment; *b*—6.3-tonne double attachment; *c*—attachment with a controllable inclination of forks for transferring packaged unit materials on flat pallets; *1*—rod; *2*—lower link; *3*—angled lever; *4*—link; *5*—lever; *6*—counterbalance; *7*—load beam, shaft; *8*—shackle; *9*—upper link; *10*—collapsing link; *11*—fork; *12*—shaft; *13*—handle

of long materials and individual units. C-shaped fork cantilever attachments are widely spread.

In addition to the necessity of self-balancing, it is important to insure a precise guidance of the attachment beneath the load to be transported. Figure 31 illustrates the main types of fork-type rotatable attachments for unit materials placed on pallets. A crane attachment with a controllable inclination of the forks designed for reloading the piles of unit materials on flat pallets consists of a load beam linked to the forks so that the forks, links and the load beam form a hinged parallelogram. The end of each link is provided with a counterbalance for each fork. An empty attachment being suspended, the pickups of the forks are located horizontally. The fork movement downwards is limited by a sliding link. Hinged to the load beam are shackles whose upper parts are connected to the crane hook. The shackle is connected to the load beam. The load beam supports mount a shaft, one end of which is rigidly connected to the shackle while the other is pivotally connected to the lever. The latter is linked to an angled lever mounted on the fork. The second end of the angled lever is connected to the control handle installed on the blade.

The materials handling attachment operates as follows. When the unloaded attachment suspends from the hook the forks are retained in the upper position by the counterbalances. If the control handle is in neutral the shackle is in the vertical position and the fork pickups are in the horizontal position. The crane lowers the attachment so that the fork is located somewhat higher than the pallet pockets, and at the same time the operator declines the shackle from the vertical position to the necessary side through angle α by manipulating the control handle. Thereby the fork deviates from the horizontal line through angle β. Tilting the fork by the angle equal to the inclination of the pallet with reference to its longitudinal axis the operator guides the fork into the pocket and after that releases the control handle. While lifting the loaded attachment the shackle returns to the vertical position and the pickups take the horizontal position.

The construction of a crane-operated load gripping ork attachment (Fig. 32*a*) provides a compact stacking of

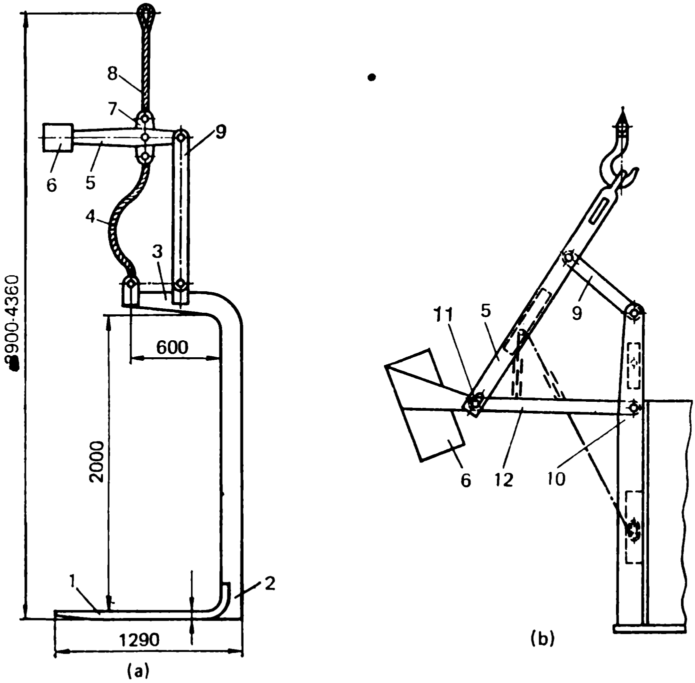


Fig. 32. Crane-operated fork-type materials handling attachment: *a*—attachment with a free lifting of the fork; *b*—attachment with pivotally connected four-link system; *1*—fork; *2*—vertical girder; *3*—horizontal girder; *4*—rope; *5*—balance beam; *6*—counterbalance; *7*—shackle; *8*—suspension rope; *9*—link; *10*—frame; *11*—pivotal joint; *12*—counterbalance link

piles in a storage space. The attachment comprises two forks rigidly secured on two interconnected vertical girders. Hinge-joined to the horizontal girder are a rope and a link. A balancing member with a counterbalance is hinged to the shackle. To provide a convenient guidance of the attachment to the load, a control handle is located between the vertical beams.

Being loaded, the attachment is suspended by a rope with a shackle and the counterbalance is in the uppermost position. When empty, the device is suspended by the link and the rope is slackened. An empty attachment is balanced and can be moved vertically by hand over a distance of 400 mm.

A load handling attachment shown in Fig. 32*b* consists of a frame, built up by two pairs of straps connected by means of tubes and by a plate which serves as a support wall for the material. Sandwiched between the straps of each pair are spacers. The fork is welded to the frame from below. The frame is linked to another frame which is similar to the first one and welded of straps separated by spacers and connected by tubes and straps in pairs. In combination both frames with links make a hinge with a counterbalance at the end. The counterbalance and the size of the hinged linkage are selected so that both in empty and loaded states the frame remains in the vertical position. In both cases the common center of gravity of the fork with the load turns out to be on the line passing through the hook. Manipulation of the attachment in the vertical plane by simple up-and-down movement makes it possible to bring it under the load which is stowed in a stack or in the rack cell. To prevent a shift and unslinging of the layers in the pile being handled, the blade-type attachments with clamps have been developed.

The attachment shown in Fig. 33*a* is used to transport and place for storage hot ingots, in particular, to convey blooms. It comprises a suspension, two side plates, foreplate, backplate, and two blades. The attachment operates as follows. A crane brings it to the cooling bed (an equipment of rolling shops upon which metal is cooled after rolling) containing blooms, thereby the suspension axle is in the *A* position which insures an equilibrium of the attachment without load (the inner surface of the blades is parallel to the floor). Having brought the blades into the openings between the pillars of the cooling bed, a bundle of blooms is caught and lifted by the blades. Concurrently, the load gripping attachment is lowered down and the suspension axle is shifted to the *B* position by the crane which insures an equilibrium of the attachment with the load. Then the crane lifts the load and moves it to the stack. The attachment is lowered onto the upper row of the blooms and the suspension axle is moved to the *C* position which provides for an inclination of the attachment due to the shift of the center of gravity from the po-

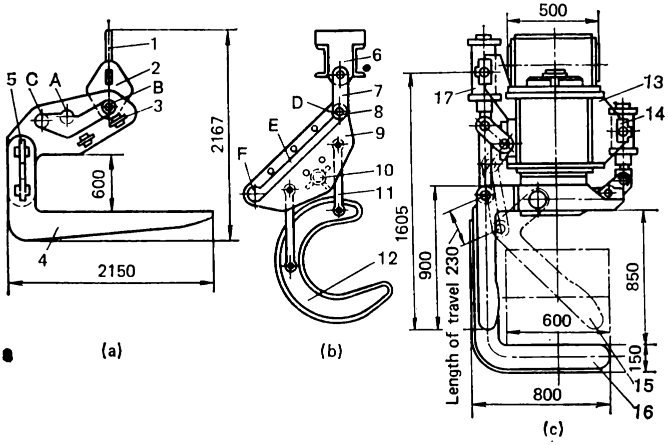
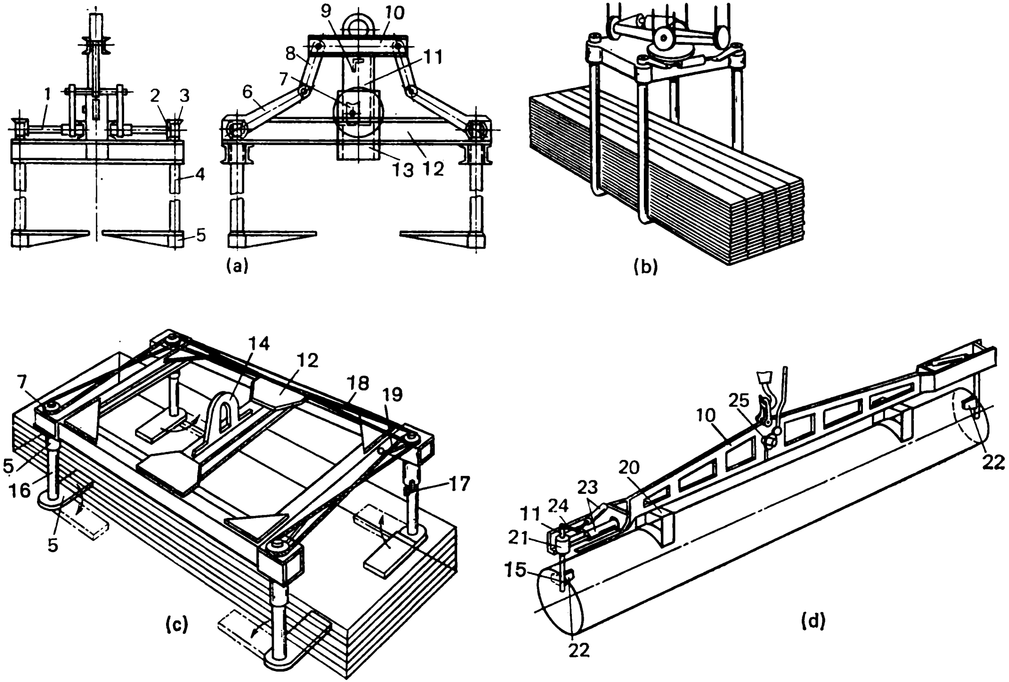


Fig. 33. Materials handling fork-type attachment for metal transportation:
a—attachment for hot rolled metal; *b*—automatic load beam for bound piles of rolled metal; *c*—attachment for rolled products (with a hydraulic drive); *1*—suspension; *2*—side plate; *3*—foreplate; *4*—blade; *5*—backplate; *6* and *13*—load beams; *7*—stirrup; *8*—finger; *9*—shackle; *10*—cross-member; *11*—link; *12*—C-shaped blade; *14* and *17*—hydraulic pusher for driving locking clips and pushing-off levers; *15*—pushing-over lever; *16*—load blade

sition of equilibrium. Blooms begin rolling off over the inclined surface to the stack and the crane is gradually moving back as the blooms are being unloaded. Having completed the unloading the crane brings the attachment to the cooling bed and lowers it onto the floor in order to shift the suspension axle to the *A* position and then to the *B* position. Then the procedure is repeated. This type of the load gripping attachment can convey simultaneously 4-6 blooms 3-5.5 m long, measuring 320 × 320 × × 350 × 360 mm and weighing up to 13 tonnes.

A load beam with a handling attachment for transportation and reloading of roll bundles 5-7 m long and weighing up to 8 tonnes is illustrated in Fig. 33*b*. Hinged to the load beam by means of a clip are two shackles interconnected by a cross-member. Each shackle has slot *E* with end holes *D* and *F* in which the shackle pin moves. Pivotally suspended from the shackles by means of links


(a)
(b)
(c)
(d)

are C-shaped blades. The load beam is hung upon the crane hook. To catch the bundle of metal the attachment is lowered down until the blades stop against the barrier. At that time the clip pin is disposed in seat *F* which is located higher than seat *D* and due to this the blades are toppled over. In further lowering of the load beam the pin slides down along slot *E* and travels from hole *F* to hole *D*. Then the load beam goes up and the shackles turn. At that moment the blades go under the bundle of metal and pick it up. The load is lifted and transported. Unloading is accomplished in a reverse order.

Load handling attachments for shaped roll (Fig. 33*c*) can be used for conveying shaped metal in piles of a rectangular and round shape. They comprise a load beam, material lifting blades, fixing clips (not shown in the figure), pushing-off levers, hydraulic pusher for driving the pushing-off levers.

To grip the load, the lifting yokes are brought under the pile and the fixing clips are turned through 5° to prevent the load from slipping off the yoke. In such a position the load is held during the entire period of transportation.

In unloading the pile the fixing clips are lowered down and the levers push the pile off the lifting yokes. This attachment can be used to transport bundles weighing up to 10 tonnes and more than 4 m long.

Materials handling attachments with vertically rotatable blades are usually used for handling packaged loads placed on supports. Wide use is made of the load handling attachments with an automatic turning of the blades via a bevel gearing during lifting to move piles of metal and other materials.

Fig. 34. Materials handling attachments with vertically rotatable blades:
a—automatic attachment; *b*—driven attachment; *c*—attachment for transporting slabs of different height; *d*—attachment for transporting large-diameter tubes; *1*—horizontal shaft; *2* and *3*—bevel gears; *4*—vertical rod; *5*—fork-type pickup; *6*—lever; *7*—sprocket; *8*—link; *9*—stop; *10*—load beam; *11*—slide; *12*—frame; *13* and *15*—struts; *14*—stirrup; *16*—telescopic rod; *17*—rotation limiter; *18*—chain; *19*—handle; *20*—horizontal support; *21*—guide; *22*—blade; *23*—hydraulic pusher; *24*—crank; *25*—pump assembly

An automatic load handling attachment of a gantry type for packaged materials (Fig. 34*a*) has four vertically rotatable fork pickups as a working member. It comprises a frame, a load beam which mounts a slide, a locking mechanism with a strut and four links hinged to four levers of the horizontal shafts. The shafts bear the bevel gears which are in mesh with the gears located at the upper ends of the vertical rods. Attached to the slide is a stop and to the strut is a sprocket which interact and periodically couple the load beam to the frame.

When the load beam is in engagement with the frame the fork-type pickups are arranged parallel to the packaged material axis so that they do not interfere with the lowering of the attachment onto the pile. After the frame thrusts against the pile top, the load beam with the slide keeps on lowering until the slide stop turns the sprocket. During hoisting the sprocket takes such a position that the slide and strut get disengaged. The load beam goes up pulling with it the links and associated levers. The levers turn the vertical shaft through 90° via a bevel gearing and the pickups go under the pile. While lowering the pile onto the pallets the load beam with the slide approach the frame until the slide stops against the sprocket. Then links go down and turn the levers and vertical shafts (with the pick-ups) associated with them via a gearing to the initial position. Now in hoisting the sprocket turns about in such a way that the slide engages the strut and the attachment is released of the load. Use is also made of a similar device but provided with a mechanism for clamping the load.

Another embodiment of the load gripping attachment (Fig. 34*b*) comprises a rectangular or square load beam suspended from the crane hook whose corners are provided with rotatable blades with shanks in a form of journals rotating in the bearings attached to the load beam. The blades are group-driven by one electric motor in order to insure their synchronous rotation. The blades can also be driven by hydraulic or pneumatic pushers. Due to a small angle of rotation it is advisable to use blade rotatable hydraulic pushers.

The pump and all the hydraulic accessories are usually mounted on the load beam, the pump being driven by an electric motor, so that the load beam is connected to the cab with electric cables only. With the blades in the extreme positions (open, close) a lamp indicator lights up in the crane operator's cab. Non-loaded blades must rotate freely to reduce the motor power.

One of the embodiments of the attachment with vertically rotatable blades which is used to grip and transport piles of unit materials of various height is a device for slab piles (Fig. 34*c*) with a hand rotation of the blades. It consists of a rectangular frame with a stirrup for suspension from the hoisting mechanism and hollow struts with rotatable gripping tools. The tools are mounted into the struts and can rotate with reference to the vertical axes of telescopic bars whose lower portions are provided with pickup blades. The top portions of the bars are interconnected by a common chain drive. Attached to the struts at an angle of 90° with reference to each other are the limiters of shaft rotation.

The drive comprises the sprockets mounted on each bar and embraced in a criss-cross manner by a chain. The chain is moved by a handle attached to one of the bars.

A load gripping attachment with vertically rotatable blades for transporting heavy tubes of larger diameter (Fig. 34*d*) is a load beam attached to the crane hook which is provided with horizontal supports by which the attachment rests on the tube. Located at the ends of the load beam are the slides movable in guide members. The slide houses the vertical rotatable posts with blades. The slide is displaced by the hydraulic pusher stem, and the post is rotated by the hydraulic pusher crank. The slide movement makes it possible to handle tubes of various length. The pump assembly including the valves with electromagnetic drive is located in the middle of the load beam and is connected to the crane cab through electric cables only.

5.2. Rocker-type Attachments and Spreaders for Containers

Rocker-type attachments are used to transport materials having through holes under which it is possible to place a a rocker rotatable about vertical or horizontal axis which takes the material weight.

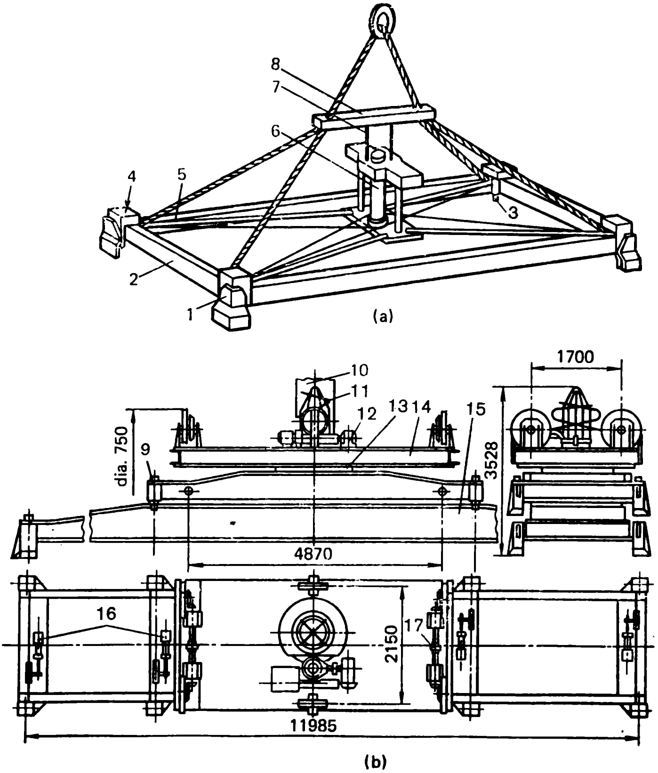


Fig. 35. Materials handling frame-type attachment for transporting containers (spreaders):
a—automatic attachment; *b*—attachment with a rotatable pin; *1*—shoe; *2*—frame; *3*—pin; *4*—sprocket; *5*—chain transmission; *6*—control unit; *7*—link; *8*—load beam; *9*—rotatable pins; *10*—casing; *11*—basket for electric cable; *12*—rotation mechanism; *13*—swing ring; *14*—block frame; *15*—load gripping frame for 1A containers; *16*—mechanism for pin rotation; *17*—mechanism for balancing rope blocks

The simplest rocker-type attachment comprises a rocker suspended by a rope or a chain from the load-lifting mechanism hook (see Fig. 13). Its capacity may vary from several kilogrammes to 60 tonnes. While selecting a rocker one should take into account that size *A* (Fig. 13*a*) is greater than size *E* by 10-20 mm. If the hole into which the rocker is inserted is larger than arm *A* the rocker will slip from the hole and the load will break away from the sling. The smallest diameter of the hole in an item which is necessary for bringing-in, turning and extracting of the rocker by hand, must be not less than 120-130 mm. If the hole in the item is small or the rocker is heavy, use is made of a line for turning the rocker from outside (Fig. 13*b*) in order to prevent the slinger's hand from injury.

Rocker-type attachments are used for transporting and mounting thin-walled floor slabs, etc.

Frame-type attachments (spreaders) may be general-purpose ones designed for gripping containers of one or several type sizes (Fig. 35). In this case the frame is made telescopic or the attachments are provided with an additional attachable frame. It is provided with a tool (cross-piece, sheaves, slings) for suspending it from the hook, and at the corners there are rotatable pins inserted into the upper holes of the fittings. The pin rotation can be hand-controlled or drive-controlled. To make the work convenient the frame is outfitted with guide shoes which embrace the container when the load gripping attachment is placed upon it. Frame-type attachments can also be provided with devices which can tilt it through an angle of up to 10° in case of gripping an inclined container. Since the containers may be unevenly filled in with goods their center of gravity is shifted therefore some embodiments of the attachments have a mechanism for longitudinal displacement of their suspension from the crane hook as far as 1.2 m.

The critical members of a frame-type attachment are pins. The mechanism of their rotation is provided with safety devices preventing the container from lifting if any of the pins failed to turn and take a required position.

A frame-type materials handling attachment consists of a so-called block frame of a rectangular shape whose corners carry rope sheaves. The rope is used to suspend the frame from the travelling gantry crane. To prevent a container from skewing and swinging in a diagonal direction the rope sheaves are interconnected by means of bevel gears. The block frame rests on a swing ring of a crane type rotatable by a mechanism consisting of an individual drive (electric motor, two-pair reduction gear, and a bevel gearing). The inner ring of the swing ring carries a rectangular load gripping frame for a container having rotatable pins at its corners which interact with the container fittings. The pin is turned by special mechanisms mounted along the shorter sides of the load gripping frame. The mechanisms comprise a screw-nut pair wherein the screw is directly connected to the driving mechanism shaft and the nut moves and acts on the rod longitudinally movable in guides, the said rod turning the cranks of the pins.

Electric motors of the swing ring and pin drives are controlled from the crane operator's cab via a flexible cable placed into a spiral chute attached to the side of the lattice structure, so-called basket, located in the device center. The screw transmission is a wearable unit of this system since the screw rotates at a great rate. To increase the service life of this nut, it is possible to use a hydraulic pusher with an individual pump assembly instead of the screw. Such a design is developed for railway transport.

5.3. Clamping Attachments

Depending on the construction of gripping members the *clamping attachments* may hold loads of different configuration. According to the method of gripping and holding materials the devices are divided into support-clamping and friction-clamping attachments (Fig. 36). Support-clamping attachments include tongs-type linkage, the free ends of the links embracing the load or its elements.

In friction-clamping attachments the load is held by the friction force resulting from its compression or outward pressure of the clamping movable members. Tongs fixtures of linkage type, rope fixtures of linkage type, eccentric fixtures, wedge-type (collet-type) fixtures and combined load gripping devices including elements of different types of attachments are widely spread in practice.

Load-gripping fixtures as compared to other mechanical devices of other types are most suitable for mechanization and automation of reloading operations. Load handling fixtures of friction type may be self-gripping and driven ones. In fixtures of the first type the clamping is obtained by the force of gravity of the load and the grippers which is transmitted to the end tools by means of linkage, pulling, spreading, wedge and hydraulic (pumpless) and other transmission devices. In the fixtures of the

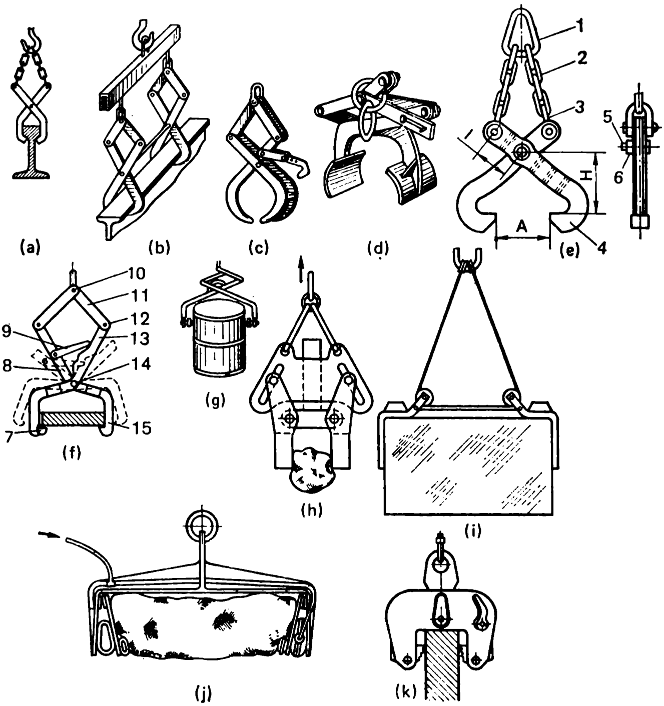


Fig. 36. Clamping attachments:
a—tongs for rails; *b*—doubled tongs attached to a load beam for handling girders; *c*—doubled tongs for tubes and rods; *d*—single tongs for tubes and round articles; *e*—tongs for hoisting and conveying metal structures; *f*—tongs for items freely supported by the blades; *g*—self-clamping tongs; *h*—friction-type attachment with a slot-slinging grip; *i*—attachment with a rope-lever grip; *j*—attachment with an inflation grip; *k*—attachment with an eccentric grip; *1*—ring; *2*—chain leg; *3*—stirrup; *4*—gripping levers; *5*, *10*, *12* and *14*—axles; *6*—nut; *7*—removable support; *8* and *13*—support levers; *9*—locking lever; *11*—lever; *15*—blade

second type the efforts are created with the help of electromechanical, hydraulic or pneumatic drives.

The schemes of linkage-type self-gripping handling attachments (systems) are diverse. An important role in designing friction-type handling devices is played by the selection of the transmission ratio. In some cases the transmission ratio depends on the necessity to have a large span of the gripping members, in other cases, on the necessity to have great efforts in gripping the materials. The scheme and rated transmission ratio of the linkage and other kinds of transmission are selected in each particular case, safety measures being also taken into consideration.

Friction-type fixtures with a hydraulic or pneumatic drive are sometimes made without any linkage which makes them lighter and cheaper. They are widely used in handling materials of a rectangular shape with smooth side surfaces: beams, bulkheads, blocks, girders, tubes, etc.

Driven load-handling fixtures can be remote-controlled. They can be used for handling materials within a wide size range. The mouth size for a certain kind of the load, its gripping and release can be controlled directly by the crane operator.

Load handling fixtures can be made in a form of elastic vessel (rings, tubes, etc.) whose shape is predetermined by the material type. Controlled gripping forces are created by pumping the vessel which is located inside or outside the load to be handled. As soon as pneumatically or hydraulically pumped vessels expand they are secured to the load.

Tongs-type attachments are made as linkage systems in the form of scissors, the levers of which have free ends embracing some protruding elements of the load, such as a flange of a beam, a top of the rail, etc.

To pick up and transport long materials several attachments are mounted on a load beam. To hold the load gripping attachments open, use is made of the latches interconnecting the tongs of the attachments which are controlled by hand or automatically and switched off when the attachment rests against the load. The locking device of semi-automatic attachments is hinged to one of the pickup blades and the stop. It is located at the inner side of another blade and insures a free release and bringing-in of the attachment before lifting the item without any participation of a slinger.

Tongs are widely used for handling and transporting tubes. They comprise a housing, two levers and a two-leg sling. The attachment is provided with a latch which locks it automatically in an open position and insures the opening of the tongs when the tubes are lowered down onto the supports. Replaceable blocks are provided for gripping tubes of different diameters.

Parameters of K3-type load handling attachment are given below:

Type	Tube diameter, mm	Load-lifting capacity, t	Weight, kg
K-111	89-114	0.75	7
K3-161	114-168	1.0	11
K3-2	219	2.0	20
K3-3	325	3.0	38
K3-5	529	3.7	108.4
K3-7	720	5.0	214
K3-12 21C*	1220	15.0	806
K3-14 21C*	1420	23.0	926
K3-8	820	6.5	313
K3-10	1020	12.0	488

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* Made for northern areas of the USSR.

Automatic friction self-clamping attachments of a linkage type are made as a linkage system whose levers have business-end tools such as pivotally connected shoes for gripping the load which is held in the gripping device by the force of friction. Load handling devices of this type are used for handling rectangular and cylindrical materials (billets, ingots, boxes, rolls, etc.). The load is clamped both by pulling in the lever tail arms and by spreading their tail arms (Fig. 37).

To insure a free fitting of the load-gripping attachment upon the load, use is made of the arrangements holding it open which comprise springs for opening load gripping

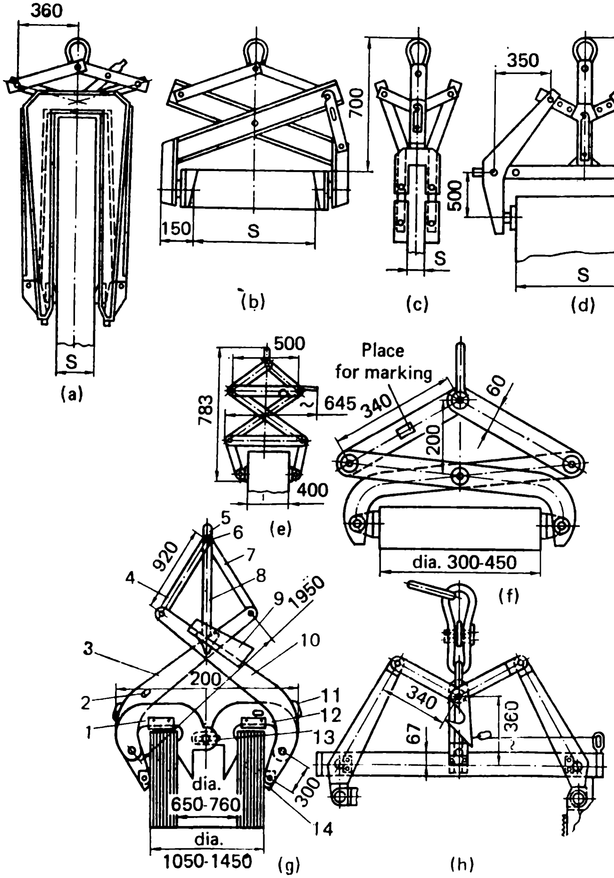


Fig. 37. Friction self-clamping attachments of linkage type: *a* and *b*—drawing-together attachments for narrow and wide items; *c* and *d*—spreadable attachment for narrow and wide items; *e*—attachment with a drawing-together linkage; *f*—the same with coincident middle pivots; *g*—attachment for steel rolls; *h*—attachment with a spreadable linkage and controlled by a coupling device for keeping the attachment in an open position; *1*—doubled U-shaped clip; *2*—stop; *3* and *4*—single jaw and link; *5* and *11*—stirrups; *6*—pin; *7*—doubled link; *8*—latch; *9*—guiding strap; *10*—doubled jaw; *12*—U-shaped clip; *13*—pin; *14*—shoes

devices or of controlled coupling arrangements which include levers with latches.

The load handling attachment illustrated in Fig. 37 is provided with an appliance for automatic removal of the load and is used for handling steel sheet rolls, etc. It has a pair of tongs pivotally connected to a U-shaped clip, a single jaw and a pair of U-shaped clips. Both clips are interconnected by a pin and can slightly travel along a slot. Pivotally connected to the upper parts of the tongs are doubled and single links which are coupled to the clip by means of a pin. Freely suspended from the pin is a latch whose oscillations are limited by a guiding strap. Hinged to the lower part of the tongs are shoes, clips and stops which limit the travelling of the U-shaped clips when the empty load handling attachment goes up.

The attachment is suspended from the crane hook with the aid of a stirrup. Thereby the pendulum-type latch is pressed to the pin and a gap is provided between the U-shaped clips and the shoes. The said gap is necessary for placing the attachment on the roll. When the crane hook goes further down the upper part of the attachment goes down too, and the rod disengages the latch from the pin. Then the roll is lifted being strongly clamped between the U-shaped clips and shoes. To release the load, the upper part of the attachment is lowered down until the mouth of the pendulum-type latch is lower than the pin. During the subsequent lifting of the load the latch mouth automatically thrusts against the pin, the tongs and the clips remain open.

In linkage friction-type self-gripping load handling attachments the business-end tools grasp the side surface of the material and hold it through the force of friction. The fixture insures a necessary force of tightening for a reliable holding of the load in the tools (Fig. 38).

Linkage-type rope self-gripping attachments comprise a rope passing over the sheaves attached to the squeezing levers. A horizontal leg of the rope increases the gripping force exerted on the load. The use of a tackle for pulling together whose legs pass over the lever sheaves, increases considerably the force of the load clamping. Such devices are widely used for handling packaged unit materials within a great size range.

Gripping tools of friction-type fixtures are made as clamping blades, shoes, or plates.

The structure of gripping members is shown in Fig. 39. Depending on the materials to be transported they are made rigid, semi-rigid and soft. Rigid clamps are made of high-carbon steel providing them with spikes, serration or smooth surface strengthened by thermal treatment. Semi-rigid clamps are made of metal with a lining of thick rubber or conveyor belt, soft clamps are made of metal with a lining of porous rubber or similar materials. The structure of clamps is selected depending on the shape, configuration, dimensions of the material and on the method of its handling. The main requirements to the shape and material of the gripping members are to provide high friction between the surfaces in contact, preservation of the surface of the material to be lifted, a long service life and intactness of the gripping surface especially if the clamp is serrated. For this in view, it is recommended that the serration of the clamps for transporting hard materials have a sharpened asymmetrical profile with the rake angle about 5° and be made of low-carbon steel 15 or 15X carbured to a depth of 0.8 mm. Surface or volumetric hardening with subsequent low-temperature tempering is also possible if steels 45 or 45X are used.

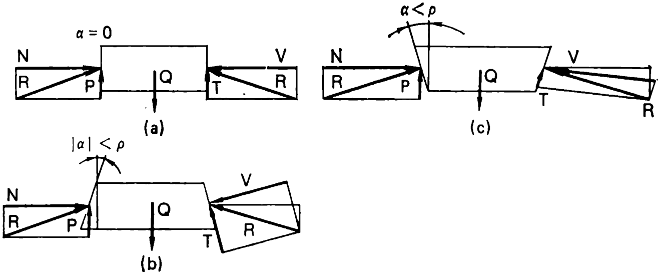


Fig. 38. Diagram illustrating item gripping

Rubber linings with a high friction factor cannot be used in handling hard or similar materials. Linings in the form of steel ropes located at a right angle to the direction of the force of gravity are more advisable for use. The pressure at a place of contact of the clamping ele-

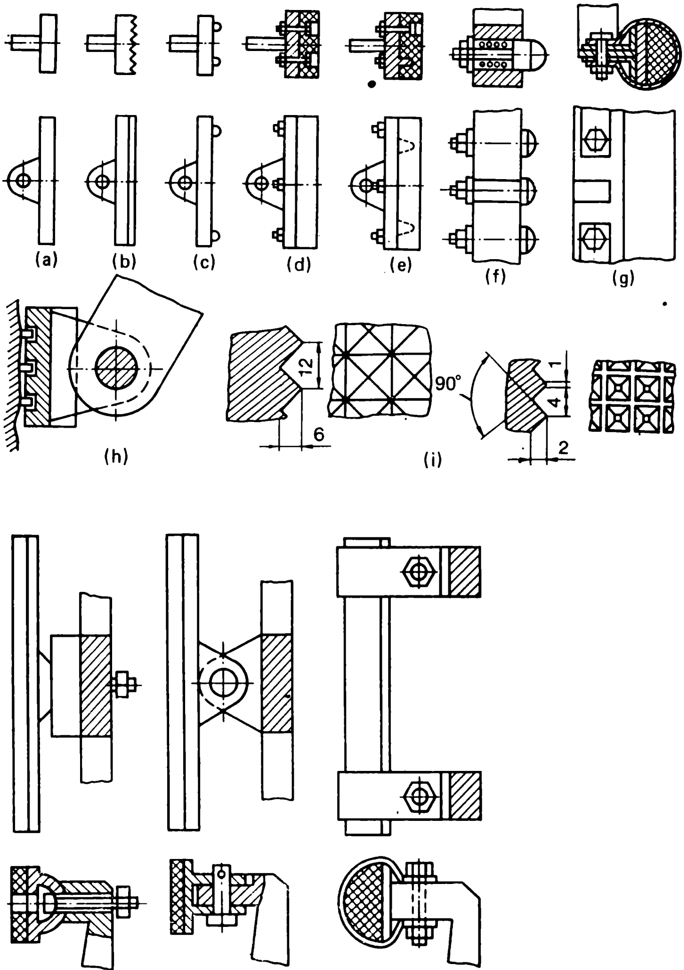


Fig. 39. Gripping members of clamping attachments: *a*—smooth metal member; *b*—serrated surface member; *c*—gripping member with spikes; *d*—member with thick rubber lining; *e*—the same with spikes inside; *f*—member with spring-loaded cams; *g*—member with porous rubber lining covered with conveyor belt; *h*—member with a steel rope lining; *i*—member with a shaped serration on the contact surface; *j*—rigid coupling; *k*—balanced coupling; *l*—ball coupling

ment with the load is considered to be varying according to a linear law in height and uniformly in width. The forces of load pressure upon the pivotal clamp (Fig. 40) (the forces N and N_0 are applied to the clamp center) are to be found from the following formulae:

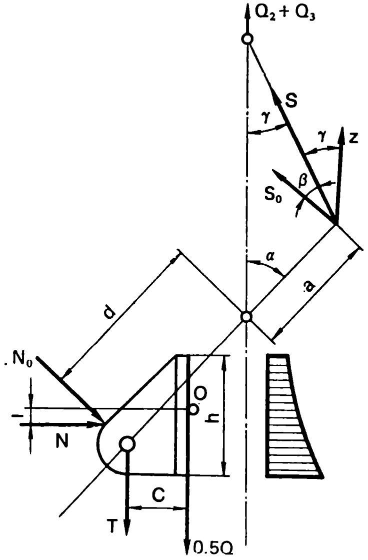


Fig. 40. Calculation diagram for determining pressure at a place of contact of gripping member with material

$$S = (Q_h + Q_v)/2 \cos \gamma; \quad S = S \cos \beta;$$

$$N = N_0 \cos \alpha; \quad T = N_0 \sin \alpha; \quad N_0 = S_0 a/d;$$

$$Z = S \cos \gamma; \quad \beta + \gamma = 90^\circ - \alpha$$

Having shifted all the forces to point 0 in the middle of the clamp we shall get the pressing force N, the moment $M = NL + Tc$, and the displacing force $\gamma = T + Q_h/2$.

Then the pressure will be: due to the force N $P_0 = N/bh$; due to the moment at the edges: $P_1 = \frac{M}{W} = \frac{M}{bh^2/6} = \frac{6(Nl + Tc)}{bh^2}$.

Finally along the edges we have $P = P_0 \pm P_1$, where b is the width of the clamp.

With $P_1 > P_0$ the pressure P becomes negative which leads to the clamp turn, to the reduction of the contact area and to a sharp increase of the pressure. Such a case will be if $P_1 = P_0$, that is at $l > h/6 \tan \alpha$. In order to have a uniform pressure, i.e. $P_1 = 0$, the following condition is to be satisfied: $P_1 = 6\,(Nl + Tc)/(bh^2) = 0$, or $Nl = -Tc$.

Since $T = N \tan \alpha$, $Nl = N \tan \alpha c$, therefore $l = -c \tan \alpha$, i.e. the pivot is not recommended to be located higher than the middle of the clamp.

5.4. Automatic Load-gripping Fixtures

The operation of load-gripping fixtures is usually put on an automatic basis by fixing the business-end tools in a position of catching the load, its conveying and release, and movement of the fixture without load. For this purpose, use is made of various interacting appliances whose members are connected to movable and fixed parts of the load-gripping attachments. Usually an automatic catch and release of the load are accomplished by successive up and down movements of the crane hook. Even an unexperienced crane operator can easily master these operations.

The use of automatic attachments for different operations (especially materials handling) increases the labour productivity and improves the safety since direct participation of man in handling the materials is not required. If orientation of the load in space is not required there is no need in additional attending personnel. The operator of the hoisting machine handles the materials by himself.

One of the advantages of the load-gripping attachments with an automatic control is the possibility of using the majority of them directly on the hook with no power supply which in addition to automatic slinging and unslinging of loads insures their quick replacement without reeving the ropes of the lifting tackle. However, a great variety of material items different in configuration, size and other parameters, creates certain

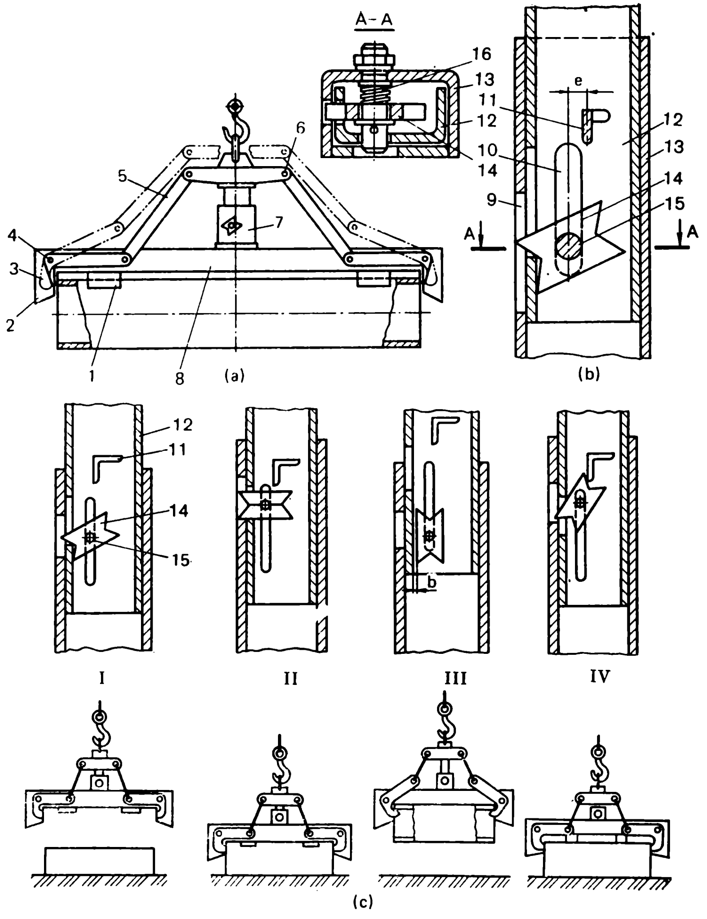


Fig. 41. Automatic materials handling attachments with a four-step mechanism for locking the gripping members: *a*—general view; *b*—locking mechanism; *c*—diagram illustrating operation of the locking mechanism; *1*—support; *2*—guide member; *3*—gripping lever; *4* and *15*—axles; *5*—rigid link; *6*—load beam; *7*—locking mechanism; *8*—frame; *9*—slots; *10*—groove; *11*—stop; *12*—slide; *13*—box-type post; *14*—freely rotatable sprocket; *16*—spring; (I—IV—steps of operation)

difficulties for mass production of automatic load-gripping attachments and prevents them from being general-purpose appliances.

Catching and clamping business-end tools of a simple structure employed by automatic load handling attachments correspond to the size of the load. If the clearance between the business-end tools is small, the automatic load pickup becomes difficult and long. If the speed of the crane movement increases, additional appliances become necessary to guide the load-gripping attachments to the load. Various appliances aimed at removing these disadvantages have been developed lately but they considerably complicate the construction. To maintain their workability and reliability, they need more careful servicing.

Most widely spread in practice are load-gripping devices having a mechanism locking the business-end tools which employ a four-step cycle. Use is also made of an automatic load handling attachment of this type (Fig. 41*a*). It consists of a frame with a guide and supports, hinged upon which are gripping levers and load beams with a shackle used to suspend the load lifting attachment from a crane hook. The arms of the pickup levers are pivotally connected by means of rigid links to the beam. The frame is coupled to the load beam via the locking mechanism which includes a box-type post (Fig. 41*b*) serving as a guide member and a slide extending there through. Attached to the post is an axle carrying a freely-rotatable sprocket. The slide mounts a stop and has a groove to receive the axles. Cuttings in the form of rectangular windows are made in the adjacent walls of the post and the slide against the sprocket. The sprocket is spring-loaded to prevent its free rotation. The box-type post is secured to the frame while the slide is attached to the load beam of the attachment. The axle with a sprocket and the stop are connected to the post and to the slide respectively with an eccentricity e due to which a torque turning the sprocket clockwise is developed.

The operation of the load handling attachment and locking mechanism is characterized by four-step cycle with the sprocket taking a definite position at each step (Fig. 41*c*).

Step I. Initial position. The sprocket is locked in the slot of the slide and prevents the post together with the frame from moving downwards with reference to the slide and the beam; it is loaded by the force of gravity of the post and the frame. The pickup levers are opened. The rigid links connecting the arms of the pickup levers and the beam are not loaded.

Step II. Lowering of the attachment onto the load. At the moment the frame sits upon the load its downward movement together with the post and subsequently with the sprocket discontinues; the crane hook with the beam and the slide continues to go down. The slide thrusts against the elongated plane of the sprocket and turns it. The lower edge of the slide slot which has locked the sprocket at step I now does not prevent it from rotation since it goes down when the slide moves down. The sprocket takes a horizontal position.

Step III. Catching the load for lifting. When the crane hook goes up the beam together with the slide moves up too, turning the sprocket by the lower edge of the slide cutting. Concurrently the rigid links turn the pickup levers whose business-end tools catch up the load. In further rising the load is pressed, detached from the base and conveyed. In such a position the locking mechanism is completely released; the force of gravity from the load, from the frame and the post is transmitted through the gripping levers to the rigid links and then to the load beam and the crane hook. The sprocket takes the vertical position.

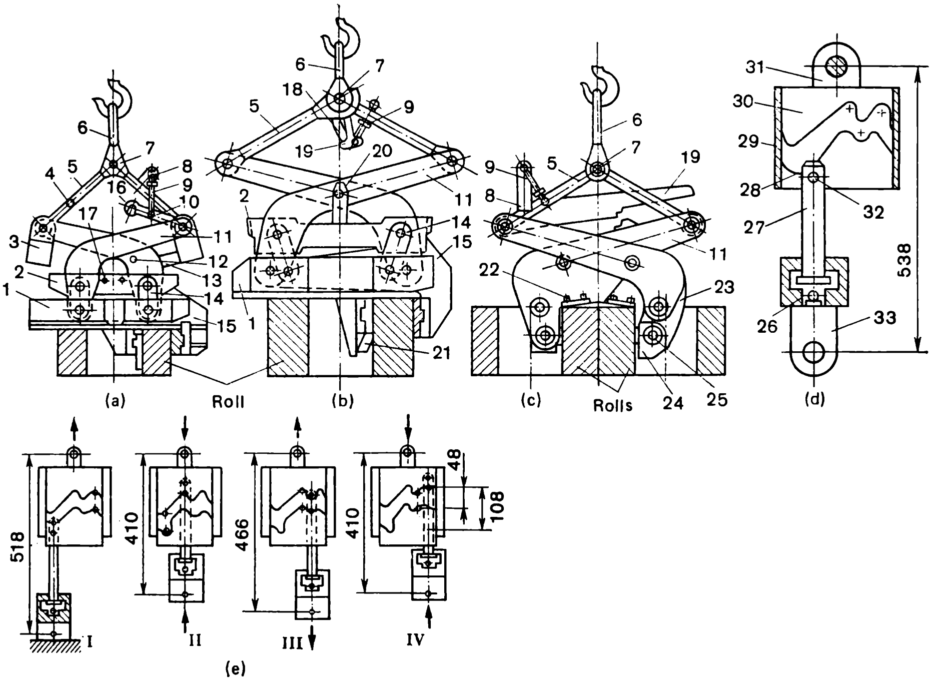
Step IV. Release of the load and placement of the load handling attachment into the initial position. At the moment the load touches the surface the frame with the post stops while the crane hook with the load beam and the slide continues its downward movement. The slide moves downward inside the post, its stop thrusts against the cutting in the sprocket and turns it. At the same time the rigid links turn the pickup levers releasing the load from the attachment. Figure 41 illustrates the moment when the slide reaches the bottom; the sprocket has turned about its axle and its tooth has entered the cuttings in the slide and the post. Now with the hook rising the slide will also go up, the lower edge of its cutting will touch the inclined surface of the sprocket tooth and turn it until it gets released. At the moment of unlocking the grip breaks away from the load and goes further up. The attachment and locking mechanism will again take the position of step I. Then the entire cycle repeats.

A relatively simple design and a possibility to make the locking mechanism as a separate unit make the attachment general-purpose one and allow the load gripping attachment to be used in various devices which become automatic in this case.

5.5. Materials Handling Attachments for Metal Rolls

To handle steel strip in rolls in the vertical position, linkage-type friction fixtures are used with a capacity of 10, 20, 35 tonnes. They employ a special stem lock for fixing the business-end tools in four positions: in empty position, in taking the roll, in lifting and conveying the roll, and in releasing the roll. A 10-tonne attachment grips one roll weighing up to 9 tonnes for movement; a 35-tonne device grips one roll weighing up to 34 tonnes; a 20-tonne attachment grips two similar rolls each weighing up to 9 tonnes for concurrent transportation. A 35-tonne load-gripping device is used for reloading rolls from a flat car to stacks and load-gripping attachments of 10 and 20 tonne capacity are used for unloading freight and flat cars.

A 10-tonne load handling attachment with an automatic control (Fig. 42*a*) comprises a pivotally connected holder, a load beam, shackles, a casing, levers and links whose common pivot carries a hoisting clamp. To insure positive operation of the device in a limited space while loading rolls to gondola cars, the levers are provided with counterbalances and their turning is limited by stops. Rotation of the links is limited by a retainer. The upper pivot of the stem lock is connected to a link through an adapter bracket, and the lower pivot of the stem lock is secured to a catch which interacts with the axle during operation. In the initial position the catch fork stops against the axle which provides the locking of the linkage system. When placing the attachment upon the roll, it gets opened completely, the eccentric turns together with



(a)
(b)
(c)
(d)
(e)
Roll
Rolls
I
II
III
IV

the lever and raises the catch. While lifting the load the catch and the axle disengage and the attachment grips the roll.

An automatic load handling attachment having a 35-tonne capacity (Fig. 42*b*) comprises a pivotally connected holder, a load beam, shackles, a casing, levers, links, and a stem lock. The pivot common for the links of the stem lock carries a hoisting clamp and a hook interacting with a strip during operation. The holder and the load beam are provided with jaws.

In the initial position the strip bears against a projection, the hook nose is stopped by the strip and this insures the locking of the linkage system. While placing the attachment onto a roll, it opens completely and the hook sliding over the plank is deflected from the vertical position. In load lifting the hook goes past the strip and the attachment catches the roll. At the places of unloading, the attachment is released from the roll and completely opens under gravity. The next cycle of operation begins.

A 20-tonne capacity attachment (Fig. 42*c*) comprises pivotally connected tongs, levers and links whose common pivot carries a stirrup. The upper pivot of the stem lock is connected to the link by means of the bracket and the lower pivot is secured on the strip whose lock interacts with the lock on the lever during operation of the attachment. Pivotally connected to the tongs are shoes freely rotatable about the axle which provides for parallel movement of the shoes during roll catching. To achieve

Fig. 42. Materials handling attachments with automatic control for metal rolls:
a and *b*—10- and 35-tonne attachment for one roll; *c*—attachment for two rolls; *d*—stem lock; *e*—position of the lock in operation; I—position of the lock stem with open tongs before picking up the roll; II—the same with open tongs in hoisting the rolls; III—position at the moment the roll is gripped by tongs; IV—position with open tongs in hoisting the rolls; *1*—load beam; *2*—casing; *3*—counterbalance; *4*—retainer; *5*—link; *6*—stirrup; *7*—common pivot; *8*—bracket; *9*—stem lock; *10*—catch; *11*—lever; *12* and *25*—axles; *13*—eccentric; *14*—shackle; *15*—holder; *16*—fork; *17*—stop; *18*—locking hook; *19*—strip; *20*—lug; *21*—jaws; *22*—support; *23*—tongs; *24*—shoe; *26*—ball support; *27*—stem; *28* and *30*—lower and upper cams; *29*—guide member; *31* and *33*—upper and lower pivots; *32*—pin

a reliable placing of the attachment onto the rolls, supports are attached to the lower surface of the tongs.

A stem lock (Fig. 42*d*) comprises two cams enclosed in a guide member. The cylindrical portions of the cams have curvilinear cuttings made so that when the cams are connected in a common guide member a template slot is provided between the cam surfaces over which the stem pin moves, the latter having a ball support. Attached by flanges to the upper cam is the upper pivot of the lock. The lower pivot is connected to the stem housing. The template slot is made so that the projections of the curve of the lower cam are shifted to a certain angle with reference to the pockets of the upper cam. During operation of the lock this insures a rotary motion of the stem always in one direction. The pockets of the lower cam curve are of varying depth as a result of which the travel of the automatic device lock also varies depending on the operations fulfilled. A compressed state of the lock is an operation position in which the attachment is completely open. During roll catching the lock is in a minimum spread position; in closed position without a roll it is spread to the utmost. Figure 42*e* illustrates four positions of the stem lock in the course of operation of the automatic load handling attachment.

5.6. Rope-driven Materials Handling Attachments

Self-gripping load handling attachments in which the drive of the business-end tools is accomplished by means of gravity forces, i.e. the tightening of the load is carried out by the weight of the load, cannot sometimes create great gripping efforts, prevent the sliding and guarantee sufficient manoeuvrability and productivity. These qualities are featured by driven load handling attachments which can be easily provided with remote control units and in some cases a complete automation of the gripping and release cycle can be achieved.

Rope-driven attachments (Fig. 43*a*) are used with the cranes having two lifting mechanisms — the main and auxiliary mechanisms which make it possible to accomplish a remote control.

Secured in the housing are axles about which rockers and shackles are freely mounted. The shackles carry the tongs. The jaws of the tongs have translational motion during closing and opening.

Free ends of the rockers are connected with levers. The said levers are free to rotate about the axles secured to the link. The second ends of the guide levers are connected to the axle upon which the rollers are fitted. Displacement of the rollers in the direction perpendicular to the longitudinal axis is limited by a groove. The link is connected to the hoisting mechanism by means of a rope, and the housing of the attachment is coupled to the unlocking mechanism. The link is provided with the slides which comprise rollers displaceable in the guide members attached to the housing.

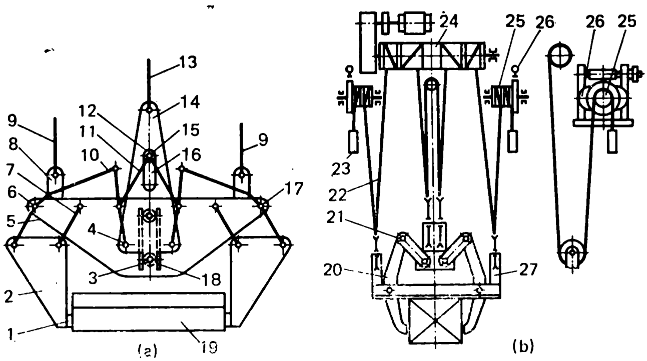


Fig. 43. Clamping attachment with a rope drive: *a*—attachment driven by an auxiliary hoisting mechanism; *b*—attachment driven by a non-driven winch; *1*—jaw; *2*—tongs; *3*—slide; *4*, *6*, *15* and *17*—axles; *5*—housing; *7*—shackle; *8*—rocker; *9*—rope of the unlocking mechanism; *10* and *11*—levers; *12*—rollers; *13*—capturing rope; *14*—link; *16*—groove; *18*—guide member; *19*—load; *20*—gripper; *21*—carrier; *22*—common rope; *23*—counterbalance; *24*—hoisting mechanism; *25*—drum; *26*—brake; *27*—load gripping mechanism

To transport loads, the attachment with the tongs wide open are brought to the load so that the load turns out to be between the jaws. Then the hoisting mechanism lifts the link, the rockers turn around, the slides move in the guide members, the tongs close and catch the load with their jaws. The jaws of the tongs are forced in one horizontal plane normal to the link axis. The operation principle of the attachment is similar to that of a two-rope clamshell.

The structure of the attachment shown in Fig. 43*b* is somewhat different. To drive this device, a crane with one hoisting mechanism can be used but it must be provided with driveless auxiliary drums having brakes. The attachment has a structure similar to that of a two-rope clamshell, thereby the hoisting mechanism is used for rotation by means of drawbars of the clamps and driveless drums support the attachment. A common rope passes over the drums (both the driveless drum and hoisting mechanism drum) which terminates in counterweights freely suspending from the driveless drum.

When the attachment in an open position is lowered onto the load the driveless drum is braked. As soon as the attachment housing accommodates itself on the load, the brake is released and the hoisting mechanism drum is engaged. The load is gripped and after the tightening force reaches some predetermined value the counterbalances begin to go up (as a result of the ropes rewinding from a sheave to a sheave). After the counterbalances reach the extreme positions, the driveless drums are braked and the load is lifted. The load handling attachment is getting open in a reverse order.

5.7. Materials Handling Attachments with Electromechanical Drive

In a load handling attachment with a mechanical drive the electric cable is usually located near the business-end tools which is not always applicable to hoisting cranes. Therefore, such attachments are of a limited use. A tongs-type clamping attachment of a charger (Fig. 44) is designed for loading ingots into heating furnaces and for removing them from the furnaces. It is mounted on the column frame of the charger having a capacity of 2-3 tonnes. The attachment columns are raised and lowered by means of a lifting tackle at a rate of 4 m per minute and are turned by a rotation mechanism at a rate of 36 rpm. The mechanisms for column rotation and hoisting are mounted upon the main trolley of the crane. Extending through the lower portion of the gantry column is an axle to which the frame is attached. It is free to rotate about the axle through some angle by means of a rolling mechanism carried by a bracket fastened to the column. Mounted to the frame is an attachment drive mechanism. It comprises an electric motor, a brake, a friction clutch, a worm-type reduction gear and a screw having left-hand and right-hand threads. Moving along these threads are nuts which are connected to the tongs by means of shack-

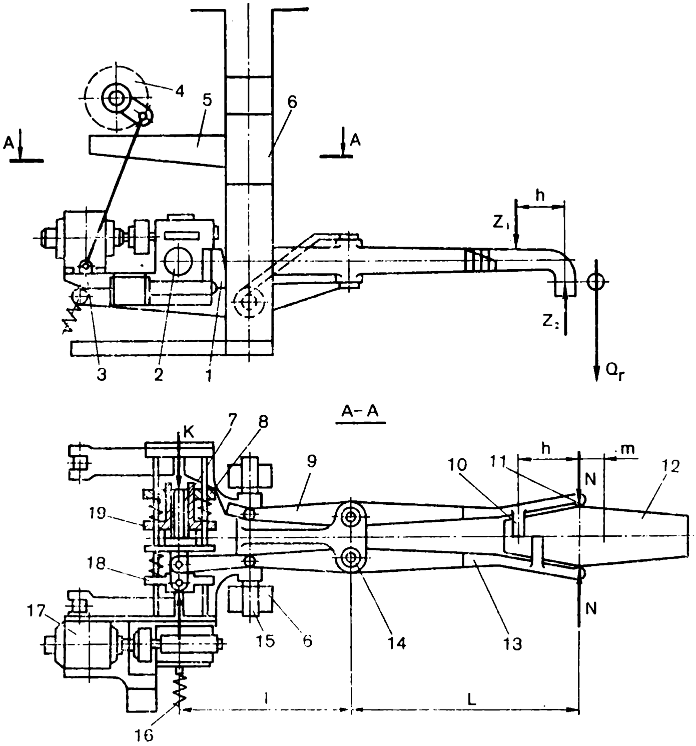


Fig. 44. Tongs-type clamping attachment of a metallurgical charger:
1—frame; *2*—worm-type reduction gear; *3*—spring; *4*—rolling mechanism; *5*—bracket; *6*—column; *7*—screw; *8*—nut; *9*—lever; *10*—boss; *11*—spike; *12*—billet; *13*—tongs; *14*—vertical axle; *15*—gantry axle; *16*—friction clutch; *17*—electric motor; *18*—shackle; *19*—shock absorber

les. The locking assemblies of the nuts have spring-type shock-absorbers which insure smooth tightening of the billets and reduce dynamic loads. To prevent the drive mechanism from breakage, provision is made for a friction safety clutch of an ultimate torque. The tongs are rotatable in a horizontal plane about vertical axes. The billet is squeezed by spikes located in the lower part of the tongs at the ends bent downwards. In catching the billet its center of gravity is beyond the limits of the tongs and is located at a distance *m* from the spikes. Due to this the left end of the billet being captured goes up and rests against one of the projections forged upon the tongs which insures reliable holding of the suspended billets.

Using a rolling mechanism the tongs can pick up the billets from the shop floor. To reduce the dynamic loads the rolling mechanism is cushioned by springs.

5.8. Eccentric and Wedge-type Materials Handling Attachments

Eccentric load handling attachments are similar to general-purpose devices. They are designed for gripping and moving flat items both in the vertical and horizontal directions. Since the contact pressure is great their use is reduced to conveying the items having hard surfaces. They are most widely used in moving sheet metal of different thickness.

Eccentric load handling attachments are divided into two groups: attachments with single-side arrangement of eccentrics (Fig. 45*a* through *c*) and attachments with two-side arrangement of eccentrics (Fig. 45*d* through *f*).

To hoist long items use is made of load beams to which several eccentric attachments are fastened (Fig. 45*g*).

Load handling attachments are made both self-tightening and with additional tightening effected by a flexible link or a four-link system.

In the attachment shown in Fig. 45*a* the load is slightly pressed by the eccentric manually before lifting. More sophisticated are attachments shown in Fig. 45*b* in which the eccentric is forced to the load to be lifted when the hoisting hook moves up. To hoist, convey and mount metal plates while manufacturing metal structures, ec-

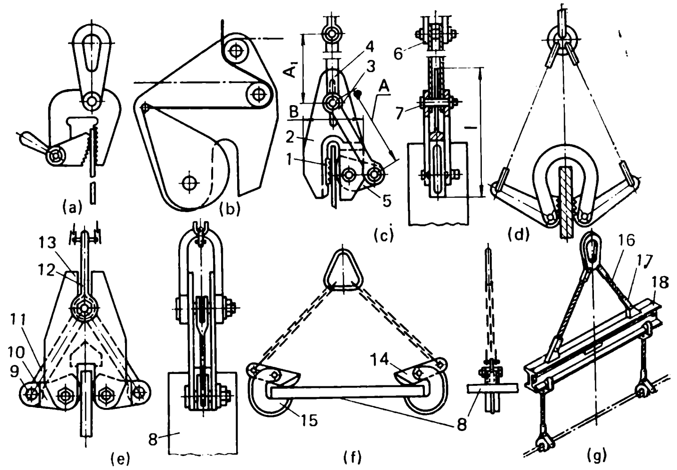


Fig. 45. Eccentric attachments:
a—attachment with one eccentric tightened by hand; *b* and *c*—attachments with one eccentric tightened by hoisting rope; *d* and *e*—attachments with a two-side location of eccentrics; *f*—attachment for moving rolled plates in the horizontal position; *g*—attachment secured to a load beam; *1*—clamping jaw; *2*—fork; *3* and *4*—links; *5*—eccentric; *6*, *7*, and *9*—axles; *8*—plate being transported; *10*—cam; *11*—lever; *12* and *15*—stirrups; *13*—side plate; *14*—eccentric lever; *16*—rope-type hoisting device; *17*—connecting link; *18*—general-purpose load beam

centric attachments of various capacity are used (Fig. 45*c*). Attachments comprise a fork, an eccentric, a clamping jaw, a link, a detachable shackle and axles. During hoisting by the detachable shackle the link connected to the shackle moves up and the eccentric presses the plate against the clamping jaw.

Technical characteristics of eccentric attachments shown in Fig. 45 are given below:

Load lifting capacity, kg	100	1600
Dimensions, mm:		
A	230	240
A_1	180	240
B	165	180
b	35	42
l	340	380
S	42	50
Weight, kg	11.6	17.8

Figure 45*e* shows an attachment with two eccentrics designed to convey metal plates. Their characteristics are tabulated in Table 9.

Table 9. Characteristics of Materials Handling Attachments with Two-side Arrangement of Eccentrics

Lifting capacity, t	Dimensions, mm							Weight, kg
	H	B	b	b_1	h	R	d	
16	340	205	45	18	78	40	26	18
25	415	240	60	24	90	46	30	28
40	380	275	65	16	74	40	36	47

Table 10. Characteristics of Eccentric Materials Handling Attachments for Moving Plates in Horizontal Position

Lifting capacity, t	Dimensions, mm						Weight, kg
	h	A	a	H	t	S	
16	0-40	225	140	200	80	60	27.4
25	15-60	245	145	260	100	61	41.4
40	45-100	330	200	350	130	61	70
80	50-100	370	240	380	130	86	123.4

The main characteristics of an eccentric attachment for transporting rolled plates in the horizontal position (Fig. 45*f*) are given in Table 10.

Wedge-type (collet-type) load handling attachments (Fig. 46) are designed for lifting and conveying the materials having a pocket with a round hole to receive spreading members of the attachment. More seldom they are used to hoist items by catching their side surfaces or protruding parts.

The main members of the most commonly used wedge-type attachments are spreading members movable in the horizontal direction and located in the item hole, and a tapered wedge movable vertically. Spreading mem-

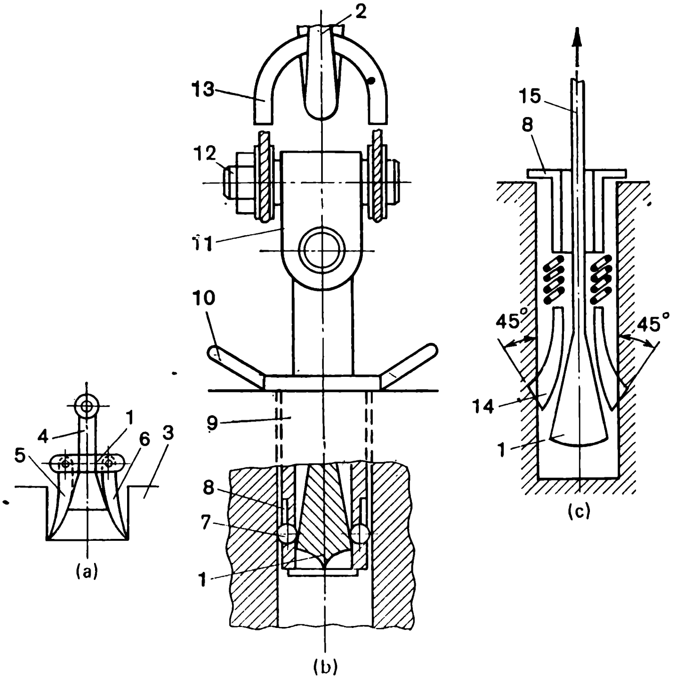


Fig. 46. Wedge-type materials handling attachments: *a*—attachments for hoisting by side surfaces; *b*—ball-type attachment; *c*—attachment for lifting by dead holes; *1*—cone-shaped wedge; *2*—hook; *3*—load; *4*—lifting link; *5* and *6*—spreading members; *7*—ball; *8*—casing; *9*—housing; *10*—handle; *11*—ear; *12*—bolt; *13*—load suspension; *14*—spreading cam; *15*—link

bers are made as cone-shaped segments, wedge-type cams or as prismatic members. To reduce the wearout and to increase the mobility, the spreading members are often provided with spherical surfaces.

5.9. Load Beams

Load beams are used for craning large-size items which are connected to the load beam in some points simultaneously by means of load-gripping attachments mounted on the load beam or by means of slings attached to the load beam. The use of inclined slings for hoisting horizontally extending long structures and heavy-weight equipment, such as girders, trusses, frames, assemblies, etc. results in the loss of the crane operation height and in considerable strains in the sling itself, great pressure exerted on the item to be lifted and in bending of the mounting loops. Slings combined with load beams (Fig. 47) are free of these disadvantages and are employed for slinging items more than 12 meters long. The load beams are made of girder-type (Fig. 47*a*) or as lattice trusses (Fig. 47*b*). Girder-type load beams are made of tubes or of two interconnected channels or angles (Fig. 47*d*) with slings attached to their ends. The length of a girder-

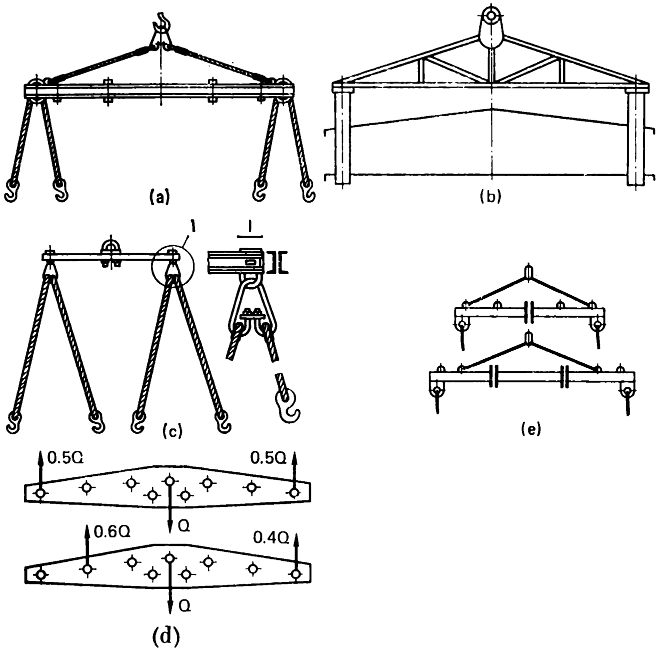


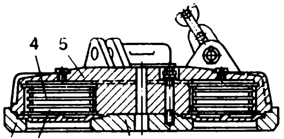
Fig. 47. Load beams:
a—girder-type beam with balancing slings; *b*—lattice-type load beam; *c*—load beam with a stirrup for suspension from the crane hook; *d*—balanced beam for load hoisting by two cranes; *e*—girder-type composite load beam of varying length

type load beam is not more than 4 m since long beams are heavy.

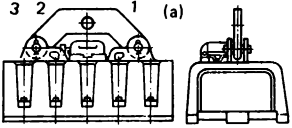
To attach slings to the girder, holes are made or plates with ears are welded (Fig. 47*c*). There may be several pairs of the plates welded to have a possibility to change the operation length of the load beams. Another method of varying the operation length of the load beam is the use of inserts in a composite girder (Fig. 47*e*). This method increases the range of the load beam employment but causes a time loss for rearrangement of the load beam. Therefore, in the majority of cases especially when handling single-type long items it is advisable to have separate load beams for each type of the materials. Lattice-type load beams more than 4 m long are usually fabricated as simple triangle trusses, the corner of the triangle facing up or down (Fig. 47*b*). In the last case the loss of the crane hook hoisting height is reduced but the load beam should be additionally checked for resistance to rotation.

Load beams are suspended from the hook by means of a pin secured in the middle of the beam, a gusset plate with an ear (ring) or links (flexible or rigid) which are pivotally connected to relieve them from bending moments. However, use of flexible or rigid links results in the loss of the useful hoisting height. Free ends of rope slings terminate in hooks of various construction which come into engagement with the shackles of the item or with pin-type grips attached to the load beam with the thimbles inserted into the seats of the lock housing. The pin is extracted manually by pulling a rope attached to it or by a pulling electromagnet.

In addition to simple rope slings the load beams can be provided with various specialized load handling attachments. Rope slings can be connected to the load beam in a balancing way by passing the sling rope over rolls secured on the beam. Such load beams are called balanced load beams and are used for hoisting the materials whose points of sling attachment are located at different heights. Equilibrium balanced load beams are used to hoist heavyweight equipment by two cranes which are often of different load-lifting capacity. In this case the load beam has two suspensions for attaching to the crane hooks, which prevents one of the cranes from overloading. The load beam



(a)



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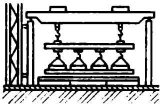
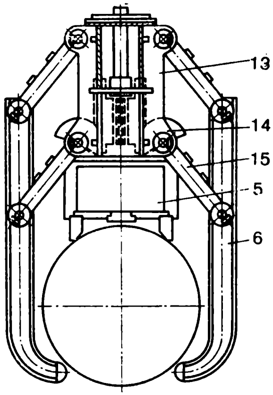


(c)



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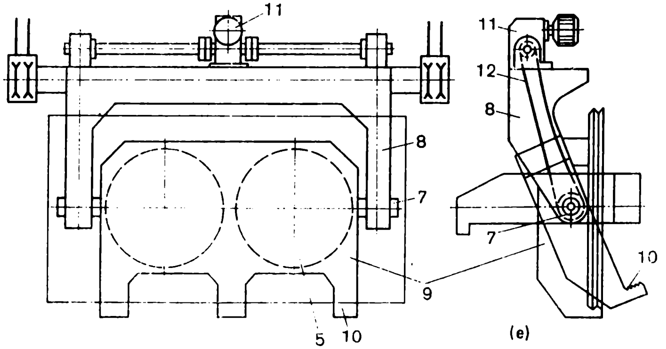
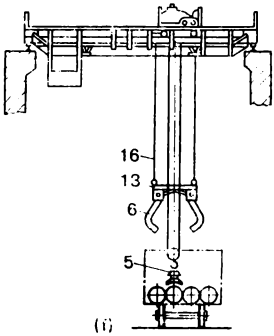


(e)



(f)

should be selected so that its design provides for the hoisting of an assembly unit in the operation position.

5.10. Electromagnetic and Magnetic Materials Handling Attachments

Electromagnetic load handling attachments (lifting electromagnets) are used for handling ferro-magnetic materials: steel and partially iron items and materials. They comprise electromagnets with a flat armature characterized by a great force of attraction in the clearance between the armature and the load closing the magnetic field. Electromagnets are usually made round or rectangular.

Electromagnetic attachments are designed for handling materials of any configuration: steel ingots and plates, iron pigs, scrap, etc. including materials heated to a temperature of up to 500 °C. The shape of the material and its temperature affect the lifting capacity of electromagnetic attachments.

At a temperature of over 200 °C the magnetic permeability and subsequently the load lifting capacity of the magnet considerably reduce and at a temperature of 720 °C the lifting capacity is equal to zero.

Figure 48*a* and *b* illustrates lifting electromagnets of a round and rectangular shape. A massive case made of steel having a very high magnetic permeability houses an electromagnet coil held from below by poles and non-magnetic washer. The electromagnet winding enclosed in a sealed shell is made of sections, each section being wound of bare copper tape. The turns of the sections are insulated with thin asbestos paper impregnated with

Fig. 48. Lifting electromagnets:
a—round magnets; *b*—rectangular magnets; *c*—several magnets secured to a load beam; *d*—magnets with a safety device for large-diameter tubes; *e*—magnets with a safety device for rolled plates; *f*—magnets with safety blades for long-cut rolled products; *1*—bracket for holding a cable; *2*—core; *3*—case; *4*—coils; *5*—electromagnet; *6*—safety blade; *7*—trunnion; *8*—housing; *9*—rotatable plate; *10*—protruding rim; *11*—plate rotating mechanism; *12*—chain transmission; *13*—load beam; *14*—drive mechanism; *15*—pivotal four-member linkage; *16*—rope

heat-resistant varnish or with glass-fibre tape and poured under pressure with heat-resistant mass which is polymerized to insure good electric and magnetic strength of the coil and abstraction of heat. The electromagnet coil is designed for 220 V D.C. with the duration of operation of 50%. The electromagnet poles can be welded or fastened mechanically. Welding insures better strength and water protection but complicates replacement of faulty members.

Electromagnetic attachments of a round shape are most widely spread. While handling long items it is possible to use rectangular lifting magnets or load beams with several (sometimes two) electromagnets suspended from it (Fig. 48*c* and *e*).

Power is supplied to the electromagnet through a flexible trailing cable. With small hoisting heights, the cable is secured with a loop and the crane is provided with spring-loaded cable reels which automatically maintain a required tension of the cable. If an electromagnet is used to hoist hot materials, the cable insulation must be heat-resistant. Electromagnets are installed on the cranes with electric drives (bridge and gantry cranes). Self-propelled jib cranes are seldom provided with electromagnets because of several reasons: these cranes are not used at the storage places of metal, scrap or chips, their payload is sharply reduced due to a great weight of the electromagnet, the cranes have no power supply and if they are provided with an independent generator, their power is usually limited.

However, an electromagnet can be mounted, if necessary, on self-propelled cranes with the use of standard equipment. An independent generator for supplying the electromagnet is installed on the crane turntable and is driven by the main engine of the crane, the generator is to be disconnected if the crane operates without the electromagnet.

While handling materials by means of electromagnets there is always a threat that the item may break away and fall down in case of accidental discontinuity of electric power or due to some other reasons. To prevent this, electromagnets are equipped with safety mechanisms having a separate electric drive (Fig. 48*e*). A U-shaped housing attached to the crane hook has pockets in which a plate with a protruding rim rotates on trunnions. Mounted into the plate are series-produced lifting electromagnets. A plate rotating mechanism connected to the trunnions via a chain transmission is located on the housing. To transport sheet metal, the plate is positioned horizontally and the attachment is lowered onto the load. The attachment with the load attracted by the electromagnet is raised and the plate is shifted into an inclined position so that the load rests on the plate and its rim. If the power is off the load will not fall.

An electromagnet shown in Fig. 48*d* designed for handling large-diameter tubes operates according to another principle. The device has a load beam from which several (depending on the tube length) lifting electromagnets are suspended. A pivotal four-member linkage is used to attach pickup blades to the load beam, the blades being brought under the tube by means of a gear linkage. The tube is safely transported even if the electromagnet is tripped since the linkage is capable of self-braking.

Approximately the same procedure is used for operation of an electromagnetic device illustrated in Fig. 48*f* which is employed for handling long-cut rolled products. The load beam is suspended from the crane trolley by ropes. Passing inside the beam are ropes of the load-lifting mechanism with a suspended electromagnet.

The hoisted electromagnet with the load rests against the movable part of the load beam which results in rotation and closing of the safety blades by means of locks, the said blades being counterbalanced. When the load beam is lowered onto the load the counterbalances open the blades. There are also other designs of the same equipment.

To insure safety in materials handling by means of electromagnets, the crane is sometimes provided with a standby storage battery for supplying power at the moment the mains is off.

5.11. Vacuum Lifters

While handling materials and carrying out mounting work in many cases vacuum lifters can be used to advantage. Their operation principle resides in the fact that in the chamber placed onto the surface of the load being hoisted vacuum is built up due to which a force of attraction is created between the load and the attachment under the effect of atmospheric pressure.

The main features of the vacuum lifters include:

convenient and quick gripping and release of the materials, especially large-size ones which cannot be provided with protruding elements for interaction by ordinary methods;

a rigid connection of the vacuum cup with the elements being transported which makes it possible to change its position in space without difficulty;

preservation of the surface of items and structures especially ground and polished ones in capturing.

The use of vacuum lifters is especially efficient in conveying and mounting the structures and articles made of airtight material with a smooth surface (glass, metal, polished marble, granite, wood, concrete, polymer materials, etc.).

The design of vacuum lifters and their employment depend on the method of building-up and release of vacuum in the vacuum chamber and on other factors.

By the method of building up vacuum in the chamber distinction is made between pump, pumpless and ejector devices. Load-gripping devices with vacuum pumps are most widely spread at present and they can be divided into the following groups:

1. Vacuum lifters in which the pump equipment is located on one frame with the vacuum cups (independent vacuum chamber) comprising general-purpose vacuum-operated gripping load beams with a flexible connection to the crane; in this case the pump equipment, inspection and control instruments are combined with the vacuum cups to form one independent vacuum-powered assembly. Independent vacuum-powered assemblies can be employed without any modification with any crane having adequate characteristics and practically they do not require any change in its structure. Independent vacuum-powered devices are controlled by auxiliary personnel (by slingers, etc.) or directly by the crane operator. In the last case the controls and check instruments are brought onto the crane operator's console.

2. Vacuum lifters in which the pump and auxiliary equipment are located on the crane frame may have a flexible and rigid connection to the crane. The use of vacuum lifters employing a rigid connection to the crane provides a possibility to mechanize handling and mounting operations. For instance, a crane or a loader provided with a manipulating jib outfitted with vacuum cups can be used for handling and mounting operations involving large-size items which are hard or even impossible to grip by the devices of another type. The use of such vacuum cups makes it unnecessary to connect ropes, electric cables and suspended air hoses from the gripping device.

3. Ejector vacuum lifters. The construction of such devices is simpler, their weight is smaller than that of the pump devices but due to the fact that there is no possibility to get the vacuum lower than 53 kPa, vacuum cups of a greater size are to be used. The employment of ejector vacuum lifters is associated with the necessity to provide compressed air via hoses to the vacuum cup which is not always possible especially when the materials are to be conveyed over great distance. Due to this, ejector vacuum lifters are used under stationary conditions for transporting articles of small weight having a smooth surface. Still wider use is made of pumpless vacuum lifters with a variable volume of the vacuum chamber which can be provided with a manual, mechanical, pneumatic or hydraulic drive and devices where the vacuum is built up by the action of the load gravity. By construction of the vacuum-forming chamber, these devices are divided into piston, diaphragm, plate and bellows-type ones.

The main advantage of pumpless vacuum lifters is their simple construction due to the absence of vacuum pumps and distributing equipment and, consequently, their independence of power sources.

In pumpless vacuum lifters the item holding is limited by the time during which the working vacuum is maintained in the chamber, therefore they are mainly used for transporting airtight items having relatively smooth surface.

Vacuum lifters have a manual, automatic and remote control. In the last two cases the valves governing build-up and release of vacuum in the chambers can be controlled automatically or according to a special program.

5.12. Manipulators and Robots

A manipulator is a controlled device or machine having a working member for accomplishing motions similar to those of the man's hand which is employed to move objects in space. Manipulators can be controlled manually (slave manipulators), remotely (teleoperators), and have various combinations of semiautomatic and automatic control, i.e. one-program (nonprogrammable) automatic manipulators (auto-operators), mechanical hands, etc.

At present manipulators experience a new advent since automation of hoisting and transportation is a key problem in industry. This is especially true for balanced manipulators with manual and remote control. They are used for mechanizing storage and erection work, mounting and removing components while servicing metal-cutting and other machine tools and mechanisms or continuous transportation plants. They can be carried by a semimovable truck or attached to a wall, ceiling, etc. Such manipulators are provided with replaceable handling attachments and are controlled from a push-button console or by means of a handle located right on the manipulator near the handling attachment. For example, a pivotal balanced manipulator mounted to a column hoists the load by means of a pivotally-connected jib powered by an electromechanical drive, the hoisting rate being smoothly adjusted within a wide range. The more the control handle is turned the faster is the hoisting. With the motor on, the load moves about the manipulator axis in the radial direction and in the horizontal plane. Using balanced manipulators, the load is moved manually but the efforts applied by the operator are small.

Manually controlled manipulators include slave manipulators in which the gripping attachment follows the movement of the control handle. In these manipulators the control handle movement is transferred to the attachment by means of follow-up systems but the required path of the attachment or load is preset by hand.

An example of an interactive control manipulator is a forging manipulator which delivers blanks from the furnace to the forging press with manual control, and manipulates the blank in the course of hammer forging automatically.

Automatic manipulators and auto-operators are used for performing similar technological operations, such as feeding of blanks to a stamping press or their removal therefrom, change of tools in machines.

Wide employment of manipulators is very promising in mining and metallurgical industries and in a number of other than machine building industries where only 10-15% of the entire pool of industrial robots and manipulators is being used now.

While manufacturing large-size forgings weighing more than 1 tonne the blanks are delivered to hammers and presses and loaded into and unloaded from the furnaces by means of various manipulators which automatize practically all the auxiliary processes and carry out the following operations: blank gripping with tongs, rotation about its axis, movement of a blank along the line of furnaces, hammers and storage place of blanks, hoisting and lowering of a blank.

If the lifting capacity of manipulators is more than two tonnes, floor-type manipulators are used whose mechanisms are mounted on a self-propelled truck.

If the load capacity is more than five tonnes, only floor-type manipulators are used; they are mounted on rail-supported trucks.

Forging floor-type rail-supported manipulators have the load capacity up to 80 tonnes. The main purpose of a forging manipulator is to support and rotate a red hot blank under the hammer. Thereby it must insure quick and precise gripping of the blank, its tilting and quick movement along the block head.

A complicated process of forging requires a sophisticated structure of the manipulator itself and its control system which would shift the blank under the hammer in vertical and horizontal directions.

The most advisable control of such manipulators is a remote control carried out by one operator.

The essence of a remote control of a manipulator resides in the fact that the operator presses push-buttons and toggles switches and gives commands to start motors in succession which accomplish corresponding motion of the end effector and orientation of the article held by the end effector.

A slave system of the manipulator remote control has a memory reference-input unit similar to the executive mechanism of the manipulator. Every degree of freedom of the reference-input unit is connected to a corresponding degree of freedom of the executive mechanism on the basis of a follow-up principle. The first one comprises reference-input elements and the second one includes executive motors. As a result, the operator can make all the links move by moving the end of the reference-input unit: this motion will be followed by the working manipulator.

A semiautomatic system of manipulator remote control is characterized by the fact that a reference-input unit is a multi-step control handle having a small shifting range. The operator controls the motion of all the manipulator drives by slightly pressing this control handle.

Remote control manipulators — command, slave, and semiautomatic ones — have a common feature: they accomplish the work only when the operator manipulates the reference-input unit. Limited actions and zone of manipulator servicing as well as a necessity to have an operator for each manipulator call for upgrading the "man-machine" system. In the final end this system must provide a required productivity of labour and maximum economic effect.

Automatic manipulators are under development which can operate according to a program changeable in compliance with the production conditions, such as for servicing an overhead conveyor in the course of its continuous operation. A manipulator is mounted on a two-axle truck travelling over overhead rails running parallel to the conveyor path. The manipulator end effector is secured to a telescopic arm which can rotate about the vertical axis of the truck and move vertically along this axis. To grip an article which is on the conveyor carriage, the manipulator is accelerated to the speed of the conveyor and travels in synchronism with the conveyor for some time during which the article is gripped and removed from the carriage. The article is transferred from the manipulator to the receiver after the manipulator truck stops in a predetermined place with an assigned accuracy. Manipulators together with the conveyor are controlled by means of a computer.

At the next stage of the manipulator development a computerized control system became an important integral part which had led to a new quality — an advent of industrial robots.

According to the ISO's definition an industrial robot is a position-controlled, reprogrammable, multi-functional manipulator having several degrees of freedom capable of moving materials, parts, tools and special arrangements and which is designed for various purposes in the course of executing different programmable motions.

The definition of an industrial robot adopted in the USSR is similar to the international definition, in particular: "an industrial robot is an automatically controlled machine, stationary or movable, comprising an executive device which is a manipulator with several degrees of freedom and a reprogrammable device for a program control intended to execute movement and control functions in a production process."

A great number of various robots has been developed for performing the work of the "take-transfer-place" type. For instance, developed and manufactured are industrial integrated robots of 5 and 10 kg lifting capacity designed for servicing presses for cold sheet stamping and die forging, embossing articles of unit blanks. Technical characteristics of these robots are given in Table 11. All the models employ a unified program control unit УМЦ-663 which widens the field of robot employment and makes it possible to use them in the set of flexible production modules and systems.

The main classes of robotic engineering systems are as follows:

(a) manipulation-type;
(b) mobile;
(c) information-controlled systems.

In manipulation-type robotic engineering systems the manipulator is the main executive member which terminates in a gripper, tool, welding head, paint sprayer, etc.

Table 11. Technical Characteristics of Industrial Robots

Characteristic	Model						
	MA5Ц4201	MA5Ц4202	MA4Ц4203	MAЦ4204 MA5Ц4204	MA10Ц4201	MA10П4202	MA10П4203
Nominal lifting capacity, kg	5/2.5	5	5	5	10/2	10/2	10
Number of degrees of freedom	4	4	4	4	4	4	4
Positional error, mm	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1	±0.1
Number of arms	2	1	1	1	2	2	1
Arm speed, m/s:							
horizontal	1.6	1.6	1.6	1.6	1.6	1.6	1.6
vertical	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Angular speed, deg/s							
of arm rotation	120	120	120	120	120	120	120
of end effector rotation	180	180	180	180	180	180	180
Drive	Pneumatic						
Consumed power, kW	1.56	1.56	1.56	1.56	1.56	1.56	1.56
Overall dimensions, mm	1250× 920× 970	1250× 920× 970	1250× 920× 970	1420× 920× 970	1420× 920× 1250	1250× 920× 1100	1820× 820× 1250
Weight, kg	370	335	340	350	375	387	365

Mobile robotic engineering systems feature a "mobile" carriage (wheeled, walking, wheeled-walking, full-tracked) having an automatically controlled drive. Manipulation-type robots are often mounted on vehicles.

Information-controlled robotic engineering systems gather information from the external sources, process it according to certain algorithms, program and deliver it to the external indicators, such as displays.

Information-controlled robotic engineering systems monitor technological processes, execute a group control of manipulation-type and mobile industrial robots, etc.

Figure 49 shows a classification of robots and robotic engineering systems. By control principles the manipulation-type robots with automatic control, including industrial ones, are divided into four kinds: nonflexible, programmable, adaptable, intellectual.

Nonflexible manipulators are practically the manipulators connected to a production line and readjusted together with this line. Programmable, adaptable and intellectual robots are quickly reprogrammable for executing various operations.

Programmable robots are reprogrammed by man and then they strictly follow the assigned program.

In the course of a technological process the adaptable robots are reprogrammed (adapted) automatically within

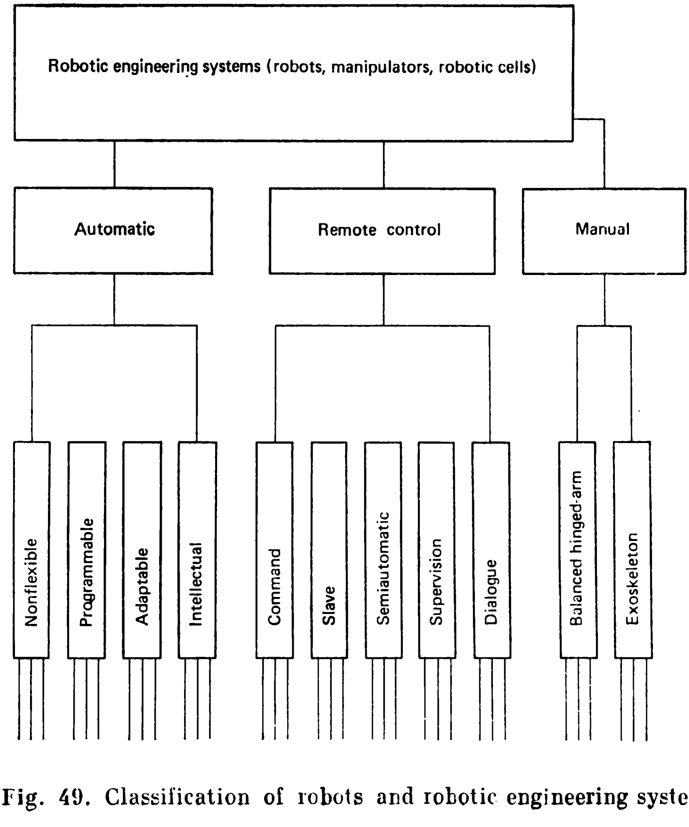


Fig. 49. Classification of robots and robotic engineering systems

certain bounds depending on the situation which could not be predetermined.

Intellectual robots get assignment in a general form and the robot itself is capable of determining its actions in a varying situation.

A supervision mode of control is such when the operator supervises a robot which can execute separate portions of the operations independently following certain programs. Therefore, a man monitoring the situation and knowing the general task preserves the right to take decisions depending on the situation. Due to this an operator gives target commands or programs to the robot which executes them independently working in an automatic mode of operation.

A dialogue mode of control presumes application of a more sophisticated robot. If in a supervision mode of control the robot behaves passively (it obediently fulfills the operator's commands), in a dialogue mode of control an active interaction of man and the robot is organized for planning subsequent actions. Down to the fact that the robot, having predicted the posteffects of the command received, can advise the operator to accept a variant of more preferable actions. A final decision is taken by the operator. The robot responding to the properties of the environment and objects which are beyond the human perception helps man estimate the situation.

A robotic engineering device is a set of robotic cells interconnected by transportation means and a control system, or some units of equipment serviced by one or several industrial robots which makes it possible to vary the sequence of equipment employment.

A governing tendency of industry development for the coming 20 years will be a still wider establishment of medium- and small-lot productions which are characterized by a broad spectrum of manufactured articles. Under these conditions the industry must have flexible production means which can adapt themselves to varying tasks and requirements of the production in a short period of time.

One of the most effective methods for solving the objective under discussion is an organization of automated production systems having a module structure and provided with module means of automation.

A flexible production module is a unit of production equipment for manufacturing articles of random characteristics within an assigned range of their properties, which is program-controlled, functions as a self-contained unit, automatically executes all the functions associated with the production, and has a possibility to become a part of a flexible production system.

A flexible production system is a combination of program-controlled production equipment, flexible production modules, separate units of production equipment and systems insuring its functioning in an automatic mode of operation during an assigned interval of time, having a possibility for automatic readjustment in manufacturing articles of random characteristics within an assigned range of their features.

An integral part of flexible production systems is transportation means which are responsible for:

— collection of blanks from the storage place and automatic transportation to the assigned place;

— loading of required blanks to the workplace;

— picking-up of finished products from the workplace and their transfer to the subsequent station or to the storehouse;

— planning of optimal routes for servicing the workplaces according to assigned quality criterion;

— transportation of industrial wastes.

Automatic transportation means used for the purpose comprise:

— floor and overhead conveyors of the linear and loop types;

— rail-supported floor and monorail overhead transportation robots;

— automatic transportation trucks.

Devices of the first and second types have a tangible disadvantage — they are insufficiently flexible in case of frequent change of the production process, therefore, they are recommended to be used only in series and mass production.

Systems employing automatic trucks possess a number of appreciable advantages: they have a flexible structure which varies depending on the production process and a high level of automation in case of quick readjustment. When provided with stacking devices and manipulators with corresponding gripping attachments, such truck can perform complicated functions of transporting robots. Thereby automatic trucks moving in a plane are most widely spread. These trucks are most effective for widening the field of employment of industrial robots.

To provide reliable functioning of production systems, intermediate accumulating stores are to be organized which are included into a complex of transportation-accumulation systems.

Transportation-accumulation systems comprise:

— stackers and rail trucks for transportation of material units, for loading and unloading of racks, receiving devices of the production equipment, and transportation devices, for distribution of material units between the basic kinds of the production equipment;

— chain and roller conveyors for transportation and accumulation of material units;

— rehandling devices for changing the direction of motion of a material unit through 90° without its rotation;

— turntables for changing the direction of motion of a material unit involving its rotation through an angle up to 360° and guiding the material unit to an inspection device;

— the system for checking the dimensions of the material unit and determining its weight in the process of the material unit motion at the entrance to the transportation-accumulation system;

— receiving rack sections for loading and unloading of stackers, rail trucks, and conveyor mechanisms;

— racks for storage of material units;

— receivers for accumulation of material units for the production equipment;

— packages are vessels for piling and transportation of materials;

— overhead conveyors for transportation of packaged and unit materials along a closed path;

— overhead pushing conveyors for transportation and accumulation of packaged and unit materials along a closed overhead route with stopping any truck on its path at a required place, transferring materials from one conveyor to the other and vertical movement;

— monorails for transportation of packaged material units through a branching way with automatic addressing;

— systems for transportation and handling operations on the floor level involving automatic loading or unloading of packaged materials to or from the moving overhead conveyor according to an assigned program as well as transportation and accumulation of material units;

— conveyor-type automatic manipulators for transferring the unit and packaged materials from the overhead conveyor to the loading stations of the production equipment and vice versa;

— transferring manipulators with manual control for handling the unit and packaged materials;

— single-girder electric travelling cranes with automatic addressing for transportation of material units, loading and unloading of rolling stock of the monorail;

— self-propelled wheeled trucks (battery-operated robot trucks) for transportation of materials involving manual or robotized loading and unloading of the trucks;

— restacking trucks for transportation of materials on pallets;

— truck tractors for conveying the materials in carts.

Under the conditions of a flexible production system the battery-operated robot trucks transport materials from stores and interstation accumulators to the production equipment and back (blanks, tools, accessories, etc.). They are also used as movable platforms for performing such production operations as welding, assemblying, inspection, etc. In each above-listed case the robot trucks are outfitted with a corresponding equipment for materials handling and other operations.

Review Questions

1. What are materials handling attachments and where are they used?
2. What attachments are used for materials handling?
3. What below-the-hook attachments do you know?
4. For what materials are clamshell attachments used?
5. For what materials are sling-type attachments used?

6. What below-the-hook attachments are used for packaged and unit materials?
7. What do blade-type attachments feature?
8. What below-the-hook devices are referred to as clamping attachments?
9. For what materials are lifting beams used?
10. What are advantages and disadvantages of attracting attachments?
11. For what materials are electromagnets used and what safety precautions are to be observed in using them?
12. In what productions are manipulators widely used?
13. What is the difference between manipulators and robots?
14. In what productions are robots most advantageous?
15. What do robotic cells and robot engineering devices mean?
16. What is the difference between a flexible production module and a flexible production system?

Chapter VI

Slinging of Materials

6.1. Selection of Slings

Selection of slings begins with assessment of the item weight and location of its center of gravity. If the item has no signs indicating these parameters, they are to be specified with a foreman or a person responsible for materials handling. In all the cases the slinger must make sure that the item to be moved can be lifted by the facilities at his disposal. Having determined the weight of the item and located the center of gravity, the slinger determines the number of places for slinging and their location to prevent the item from tilting or turning. With this taken into consideration a sling or an adequate attachment is selected out of those the slinger has at his disposal. At the same time one must take into account the length of selected sling-type attachment.

When selecting the sling length one must proceed from the fact that at a small length of the sling the angle between the legs will exceed 90°, and at a long length the height of hoisting is reduced and the item may spin. The most favourable angles between the sling legs are within the range of 60 and 90° (Fig. 50). While selecting slings one should also determine of what elements the flexible portion of the sling is to be composed (steel rope or a chain, a load beam or another kind of rigid slings, etc.) and what business-end tools are to be used for lifting a particular item of the materials. Before starting the work, it is necessary to check thoroughly the condition of the hook suspension, the hook, and the hook casing.

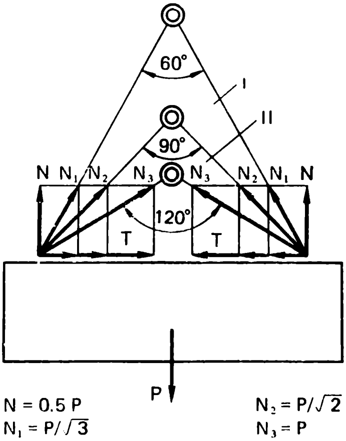


Fig. 50. Diagram illustrating distribution of load among sling legs:
I—recommended load distribution; II—non-recommended load distribution

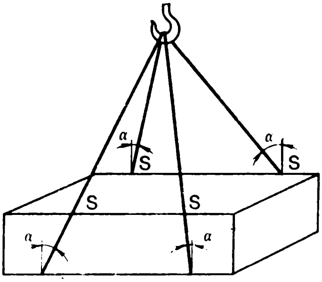


Fig. 51. Item slinging with a four-leg sling

Any fault detected, the crane operator must immediately report about it.

Selection Procedure

Having determined the weight of the load to be lifted, the slinger must correctly select a sling taking into consideration the strains which appear in each of its legs. The load applied to each leg varies depending on the number of places by which the item is hooked, the item size, the angle between the sling legs, and the length of the legs. The forces arising in the legs of the sling during hoisting can be determined by the number or length of the legs (Fig. 51). The load applied to each sling leg can be found from the formula

$$S = Qg/nk' \cos \alpha$$

where Q is the item weight; n is the number of sling legs; α is the angle between the upright axis and the sling leg; k' is the factor of load diversity with reference to each leg which depends on n; g is the free fall acceleration ($g \approx 9.8$ m/s^2). To simplify the calculations let us substitute $1/\cos \alpha$ for coefficient m. Then we shall have the formula $S = mQg/nk'$. The values used in the formula are given below:

Number of sling legs n	1	2	4	8	—	—	—
k'	1	1	0.75	0.75	—	—	—
α, deg.	0	15	20	30	40	45	60
m	1	1.04	1.06	1.16	1.31	1.41	2

While lifting an item weighing 10 000 kg by the sling with $n = 4$ and $\alpha = 45°$

$$S = 1.42 \times 10\,000 \times 9.8/4 \times 0.75 = 46\,390 \text{ N}$$

The load-lifting force per sling leg is equal to ~50 kN.

While calculating the forces in the sling legs by the second method we shall measure the length C of the legs (in our case it is 3000 mm) and the height A of the triangle formed by the sling legs (in our case it is 2110 mm). The values obtained we substitute into the formula

$$S = QCg/Ank'$$

The load per sling leg is

$$S = 10\,000 \times 3000 \times 9.8/2110 \times 4 \times 0.75$$
$$= 46\,450 \text{ N} \approx 50 \text{ kN}$$

The load applied to one leg of the sling is directly proportional to the angle between the legs and inversely proportional to the number of the legs. Therefore, in order to lift a load by the slings available the slinger must see that the load per leg is not higher than that stamped on or indicated on the tag attached to the sling. In accordance with the rules launched by the Inspection Agency the load capacity of the slings having several legs is calculated assuming that the angle between them is 90°. Therefore, using group slings the angle α should not exceed 45°. If the item is tied about by one-leg slings, such as light-duty slings designed for vertical hoisting ($\alpha = 0°$), there is a necessity to take into consideration the change of the angle and, therefore, the loads applied to the sling legs.

In slinging an item with group slings the load applied to its legs (if there are more than three of them) is unevenly distributed in the majority of cases, therefore, the slinger must hook the item so that after hooking and tightening all the legs are symmetric, equally loaded and have the same length.

Employment of Slings

With reference to the length and load capacity the slings are to be selected with due allowance for the weight and dimensions of the main types of materials to be transported at this site. One should avoid to prepare slings which are too long, have big loops and are of an increased capacity, since they are not handy in use. To prevent the slings from premature wear, use should be made of the spacers which are to be placed at protruding corners and projections. Each slinger must have a set of spacers. Alongside with specially made spacers, it is allowed to make use of wooden bars, boards, tube portions, pieces of rubber-impregnated belts, etc.

While hooking an item one should see that the places for slinging (trunnions, hooks, loops, ears, especially windows, cuttings after gas welding) are well ground and rounded. Ears, loops and hooks of the packages used for transportation of small-size articles, chips, and waste must be of round cross section and their diameter must be not less than two diameters of the sling rope. To make tilting and transportation of large-size heavy-weight items convenient, they must have special mounting loops, windows, etc.

When slinging materials one must be careful that the sling forms no loops or that no individual strands are pulled out of the rope. This will result in an undue wear of the rope. To preserve the rope and prevent the entire rope and its separate wires from wearing-out while lifting a load, the latter should be hooked by its center of gravity and the sling ends be symmetric and have equal length as far as it is possible. One must keep from hooking the sling between the component parts of the item and from pulling the slings from under the load by the crane for which purpose the pallets or spacers are to be placed under the load beforehand.

Keeping in mind that tilting of components on tilting sites is safe due to absence of people over there and that during tilting the ropes are rapidly worn out, slings of 100% fitness are not advisable to be used in this operation; it is better to use worn-out slings of somewhat greater capacity. While transporting components and assemblies having sharp edges, it is better to use chain or combined slings with chain inserts. The service life of slings with suspendable load handling attachments is longer than that of the slings designed for tying the load around since the ropes and chains of these attachments do not touch the load directly, therefore their wear-out is smaller. For this reason, the main trend in developing the load handling attachments is to make the best use of these very attachments.

The service life of slings is predetermined by their storage conditions. To this end, it is necessary to prepare special grounds protected from rain and snow. Light-duty slings are better to be stored when hung so that they do not twist, while heavy-duty slings are to be stored on wooden supports separately one from another and from other tools and equipment. The storage area must be dry and clean. After use the slings must be wiped dry, cleaned and greased. In the course of employment they are to be regularly put through technical inspection.

Technical Inspection of Materials Handling Attachments

Technical condition of materials handling attachments is checked by inspection and testing. They are liable to technical examination (Table 12) before entering into operation and periodically in the course of employment. Load-gripping attachments are not tested if they are brand new, have been tested by the Manufacturer and are deprived of visible faults. While inspecting an attachment one is to check its general condition and the extent of wear-out of the clamps, nuts, pins, splicings, welded joints, shielding, etc. If attachments are not rejected in the course of visual inspection they are tested under load. For this purpose, using information from the certificate, log or by calculations the maximum working load is found. The testing load must be equal to the 1.25 maximum working load.

Table 12. Inspection Code and Periods for Materials Handling Attachments

Attachments	Time intervals		Testing load	Time of stay under load, min
	inspection, days	testing, months		
Steel and hemp ropes, chains, slings of all types, hooks, load handling attachments, snap hooks, loops, stirrups, S-members, eyes, pins	10	6	1.25P	10
Hooks of load-hoisting mechanisms	10	12	1.25P	10
Load beams, rockers	180	12	1.25P	10
Tongs and the like attachments	30	6	—	—

Note. Slings, materials handling attachments and packages are to be inspected daily before use.

During testing a calibrated load is gripped by the attachment to be tested, lifted by the crane to a height of 200-300 mm above the floor level and kept there for 10 minutes. At many works there are stationary testing rigs. If after testing no damage, breaks, cracks, residual deformation are noticed on the attachment, it is found fit for service. Residual deformations are found by comparing the rated dimensions of attachment members before the test with actual dimensions after the test. If the attachment members have received residual deformations which are not permissible according to the code requirements they are allowed to be used only after careful inspection and recalculation for a new load-carrying capacity and subsequent testing. The tested attachment is provided with a tag, whereon a load-carrying capacity and the date of testing are indicated.

The results of technical inspection are entered into the register of handling attachments. The register contains complete information about each attachment: serial number, purpose, technical characteristics, the Manufacturer, date of munufacture, final report of the Quality Control Department.

At each enterprise, building site, depot where there are load-hoisting cranes an engineer or technician is appointed to be responsible for operation of cranes, load handling attachments and for their technical inspection.

6.2. Types of Knots and Their Use

While carrying out repair and mounting operations on metallurgical equipment and also while fulfilling occasional hoisting and movement of separate items, it is expensive and labour-and-time consuming to manufacture special sophisticated attachments.

In carrying out such work a slinger usually uses pieces of ropes or general-purpose slings employing various knots and loops for load fastening.

Square knot (Fig. 52*a*) is used for lifting a load and for connecting the ends of sling ropes of a similar thickness. To tie such a knot, the ends of the ropes are passed one about the other, are bent in opposite directions and then are passed in the same way. One must see that the knot is tied correctly: in a correctly tied knot the dead and live ends of each rope are at one side. The most frequent error in tying this knot is an incorrect direction of

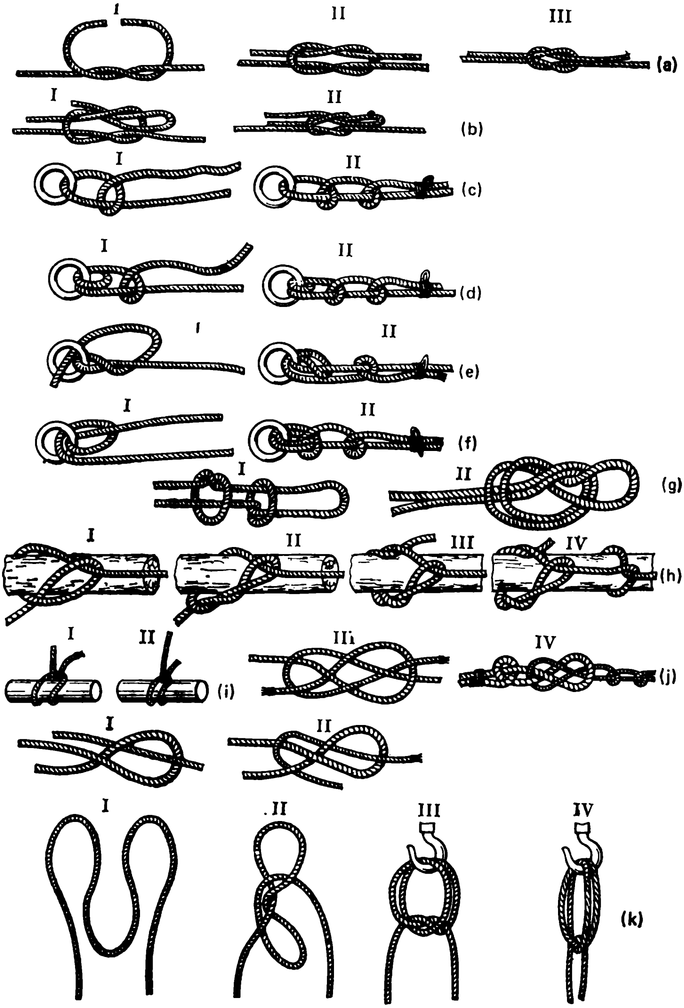


Fig. 52. Knots for load binding:
a—square knot; *b*—reef knot; *c*—two half hitches; *d*—two half hitches and two loops; *e*—two half hitches and a pass; *f*—two half hitches with two loops and a pass; *g*—sailor' knot; *h*—timber hitch; *i*—builder's loop (slip knot); *j*—granny knot; *k*—sheep shank knot (I through IV—succession of knot tying)

the second pass of the dead ends due to which the dead and live ends are found at different sides of the loops. Bear in mind that a square knot is strongly tightened at a great tension and it is difficult to untie it. To prevent the rope from sharp bends and to make the untying easy a tube piece or a wooden bar is inserted between the knot loops. When tensioned the loaded falls of the ropes must be along one line. To prevent the knot of connected steel ropes under load from getting spontaneously untied, the dead ends are secured to the live ones by clamps or tied with wire.

Reef knot (Fig. 52*b*) is a variety of the square knot. It is used for tying hemp ropes, strings and cords when its quick untying is required. This knot is not used for hoisting heavy-weight loads. The knot is tied in the same way as the square knot but one of the dead ends of the rope is inserted into a corresponding loop having folded it in two which makes it possible to untie the knot by pulling one end out. While tying a reef knot one must pay attention to the correct position of the ends in the loops.

Half hitch is used for connecting steel ropes, for tying steel and hemp ropes to various objects and items having eyes, eyebolts, trunnions, supports, etc. when a square knot cannot be used. The dead end of the rope is secured to the live end by clips or wire. Two half hitches (Fig. 52*c*) are tied in the following way: the dead end brought in the eye or led around a support is passed about the live end of the rope and is reeved through the loop formed. Thereby a half hitch is formed. Such a step is repeated 1-2 times and the dead end is tightly fixed to the live end with a piece of soft wire. A half hitch with two loops (Fig. 52*d*) is used to secure steel ropes to other objects and in other cases when the rope is under heavy tension. While tying up the knot the dead end is passed about the object two times and then it is tied up as a half hitch including attachment of the dead end to the live one. A half hitch with a pass (Fig. 52*e* and *f*) is used in the same cases as a half hitch with two loops. However, it is not recommended for attaching steel ropes because of severe bending conditions in the passing loop.

Sailor's knot (Fig. 52*g*) is used to form a temporary non-tightening loop in hoisting, suspending from the hook, drawing items, in securing ropes to the parts of a larger size. The knot holds the load well, is easy and quick to untie, and its dead end requires no clamping.

Timber hitch (Fig. 52*h*) is used for tying the ends of hemp ropes in hoisting light-weight loads. It is strongly tightened, holds well, is suitable for lifting smooth items. To make it, the rope end is passed about the item, led around the live end of the rope (I) and is turned about the bight applied to the subject several times forming a knot (III).

To increase the strength of the knot it may be provided with an additional bight (IV). In this case the knot is called a timber hitch or a half hitch.

Builder's loop (Fig. 52*i*) is used for slinging various light-weight and heavy-weight loads, small-size and bulky structures by means of general-purpose and light-duty slings. A builder's loop strongly tightens the item, hoists it easily and is easy to untie. Such a loop is not used for attaching the rope to the crane hook since an unwanted detachment may occur. While using a builder's loop for slinging loads the rope is to be applied turn-to-turn leaving a dead end whose length must be not less than 20 diameters of the rope.

Granny knot (Fig. 52*j*) is used for joining ropes of different thickness (the diameter ratio being 1 : 2) and also for joining steel ropes since in this case the rope is less subjected to contractions and bendings which is typical of other knots. It is easier to make this knot if the rope ends are placed over a flat surface. A fall of the thicker rope is arranged in the form of a loop and a fall of the thinner rope is placed under the loop and subsequently led over the live end top under the dead end of the thicker rope. Then the thin rope is led over the thick rope loop top but under its live part. Thereafter the dead ends of the ropes are tied by means of half hitches (by looping about the live ends) and are secured by means of a jackline or soft wire if steel ropes are used.

Sheep shank knot (Fig. 52*k*). The knot is done in the following way. The sling to be shortened is placed over a smooth surface and two loops are made (I), then one loop is passed about the other (II) and both loops are applied to a hook (III). Thereafter the sling turns out to be

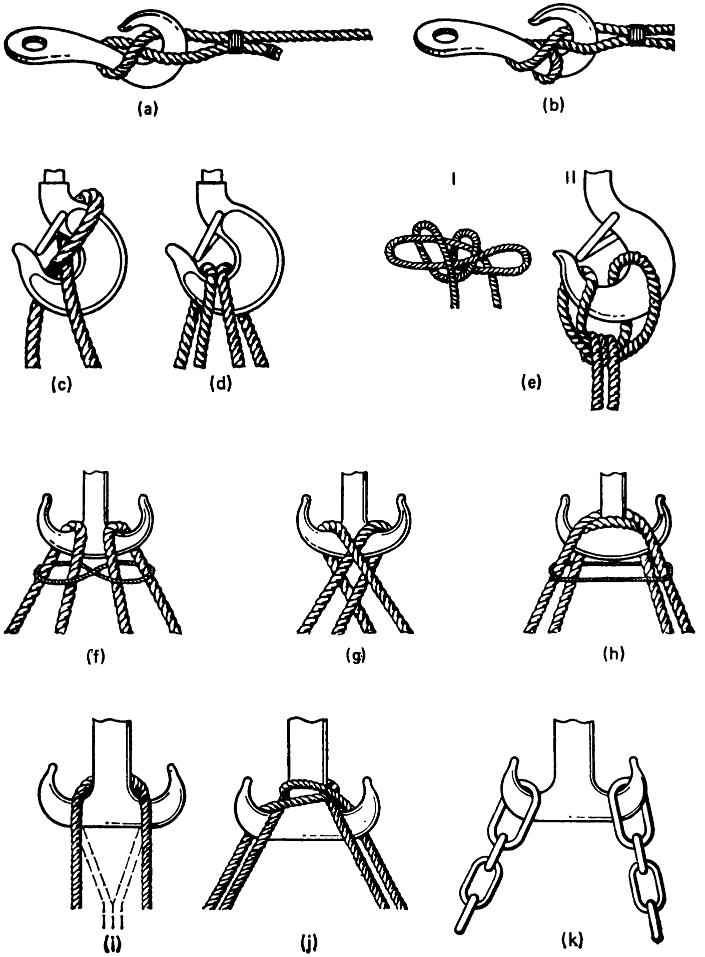


Fig. 53. Blackwall hitches (hook knots):
a—simple blackwall hitch; *b*—hook knot with overlapping; *c*—loopless knot with overlapping; *d*—loopless knot; *e*—stunner knot; *f*—loopless knot with a simple putting on a sister hook; *g*—the same with a criss-cross putting; *h*—loopless knot with a criss-cross putting behind the shank of a sister hook; *i*—the same witha simple putting; *j*—loopless knot made by a criss-cross putting with overlapping on a sister hook; *k*—loopless putting of chain slings upon a sister hook (I—before tightening; II—after tightening)

shortened by the length of one loop (IV). The knot gets untied after the loops are removed from the hook.

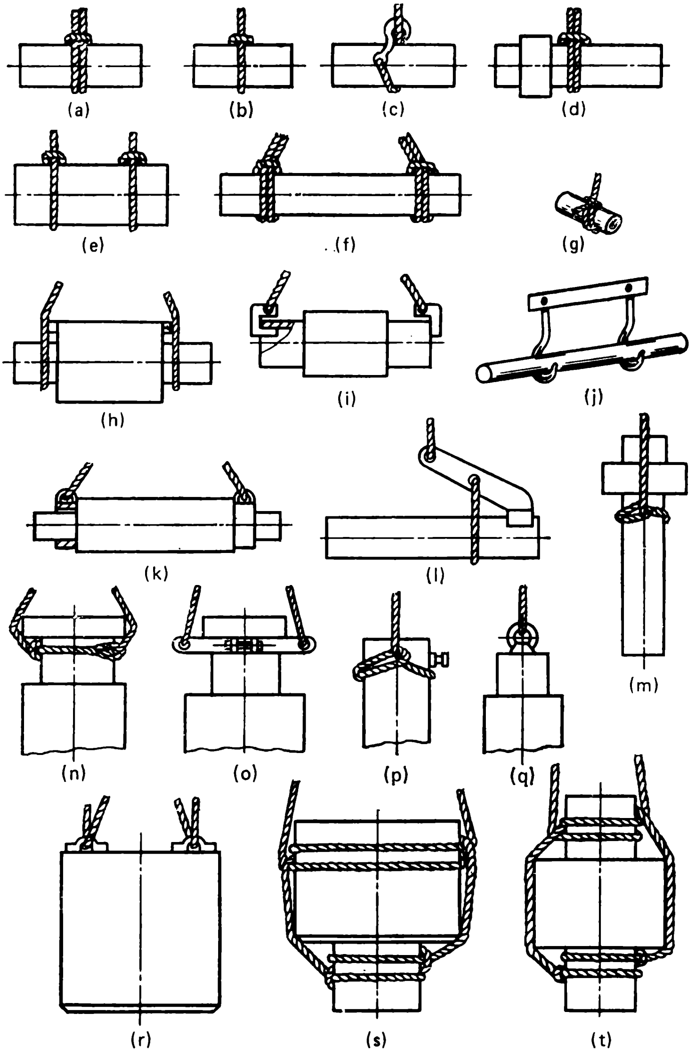
Blackwall hitches (hook knots) are used for connecting a dead end of the rope to a hook. The dead end is passed about the back of the hook, placed into the mouth and covered by means of the live end of the rope (Fig. 53*a*). Both ends of the rope are secured under the hook by means of a soft wire. To provide for better rope holding, the dead end is passed about the hook twice (Fig. 53*b*) and then is placed into the hook mouth and is covered by the live part of the rope. The knot made in this way is called a blackwall hitch and a half hitch. Having made a hitch with the use of both methods, it is necessary to check that the live end of the rope presses the dead end against the hook in its mouth.

Crane blackwall hitches are used for attaching slings to sister hooks of the cranes. There are three ways of making hitches. In all the cases the slings are to be levelled when they are under a little tension. In case of a simple application of slings to the hook noses (Fig. 53*c* through *f*) in order to shorten and increase the safety of the work, the slings under the hook are held by a retainer made of a steel rope by splicing to form a ring. The length of the retainer must be such that when the slings are taut it holds them and does not fail during tightening of the slings. In case of a criss-cross application (Fig. 53*g*) the slings are put onto opposite noses of the hook, thereby one of the slings presses the other one.

Putting of slings upon two noses of the hook (Fig. 53*h*) is most reliable. It is used when a load swinging is possible. In this case the slings are arranged so that both of them wrap the hook shank and rest on its both noses. While bringing in the slings under the load they are clamped under the hook by a retainer.

Review Questions

1. What knots are used for slinging the items provided with eyes, supports and ears with the help of steel ropes?
2. What are blackwall hitches and when are they used?
3. What knots may be used to join steel ropes in case of necessity?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6.3. Slinging of Standard Items

Slinging of shafts is one of the simplest operations. Shafts are symmetrical bodies with the center of gravity located along the rotation axis in the center of the item. They are often slung by general-purpose and light-duty slings. For transportation in the horizontal position short shafts can be tied with a knot at one point (Fig. 54*a* through *d*). Long and heavy shafts are slung with two knots (Fig. 54*e* and *f*). If the angle between the legs of the slings is small and the slings do not run together a simple grasp can be used for slinging short shafts (Fig. 54*g* and *h*). Several long shafts to be transported simultaneously must be slung at two points with a slip (running) knot or with a double envelopment. If several items are being hoisted at a time one should see that all of them are of equal length. To sling hollow shafts and assembled shafts with drilled centers, hooks are used (Fig. 54*i*); shafts with necks are slung with the help of clamps (Fig. 54*k*). Long shafts, round bars stacked into racks are advisable to be transported by an open side hook beam (Fig. 54*j*). If the end of the shaft being transported is to be brought, for instance, into a machine chuck and the item cannot be grabbed by the center, a lever attachment with a remote plate (Fig. 54*l*) is used for hooking. Transporting shafts in the vertical position is more labour consuming. Smooth, well machined shafts in such a position can be

Fig. 54. Slinging of shafts:
a—slinging by an endless rope sling using builder's loop; *b*—slinging by a single-leg sling with two loops; *c*—the same with a loop and a hook; *d*—slinging by an endless chain sling using a builder's loop; *e*—slinging by two single-leg slings using a builder's loop; *f*—slinging by two endless slings; *g*—slinging by a rope sling using a builder's loop; *h*—slinging by an endless sling with simple envelopment; *i*—slinging by single-leg sling with two hooks; *j*—slinging by an open side hook beam; *k*—slinging by clamps; *l*—slinging by a lever attachment with a remote plate; *m*—slinging by a light-duty sling using a running knot with a shift from the center of gravity in the direction of the cam; *n*—slinging by a light-duty sling using a running knot in overlapping; *o*—slinging by a sling with a split clamp; *p*—slinging with a pin; *q*—slinging by an eye; *r*—slinging by stirrups; *s* and *t*—slinging by a double running knot

moved only by means of special grips. For shafts with shoulders and grooves at the ends use is made of light-duty slings.

The load is enveloped with a running knot (Fig. 54*m*) and sometimes a split clamp (Fig. 54*o*) is used. If there is a hole in the shaft end or such a hole can be drilled, it is preferable to employ pins for slinging (Fig. 54*p*). While transporting shafts in the vertical position it is necessary to use holes in the shaft end faces into which an eye bolt can be screwed (Fig. 54*q*) or stirrups are secured (Fig. 54*r*). To transport short barrel-shaped shafts in the vertical position, they are often slung with two running knots (Fig. 54*s*). While slinging shafts they are to be tied about their center of gravity otherwise they can slip off the sling. Finely machined shafts are recommended to be slung with hemp or steel armoured slings. Crankshafts with ground necks are to be removed from the machine tools and mounted thereupon by means of steel pick-ups provided with protective tubes of rubber, felt, polymer and other soft materials safeguarding the machined surfaces against damage. Shafts delivered for thermal treatment are advisable to be moved with shackles or yokes. In case of slinging the shafts in groups, bars with shackles, shackles and spiders (Fig. 55) are used.

Drums to be conveyed in the horizontal position are slung by a simple embracing (Fig. 56) with the angle between the sling legs not more than 60°. Long items are slung in the same way but two cranes are used for their transportation, the sling legs being vertical. Drums 3-5 m long are tied up by ordinary envelopment but the slings are passed inside the item reliably securing the load.

Cross-members are often welded into the drums whose flanges are machined; they can be used for slinging. Drums and sleeves can be slung with the use of a special marked bar by means of two or one endless sling having passed it through the drum. Drums without flanges are advisable to be transported by means of grips which are used for slinging sheet metal. To sling heavy lined drums, use is made of the stirrups secured to the drum flanges by pins. To move drums in the vertical position, they are slung by embracing through holes, by means of a

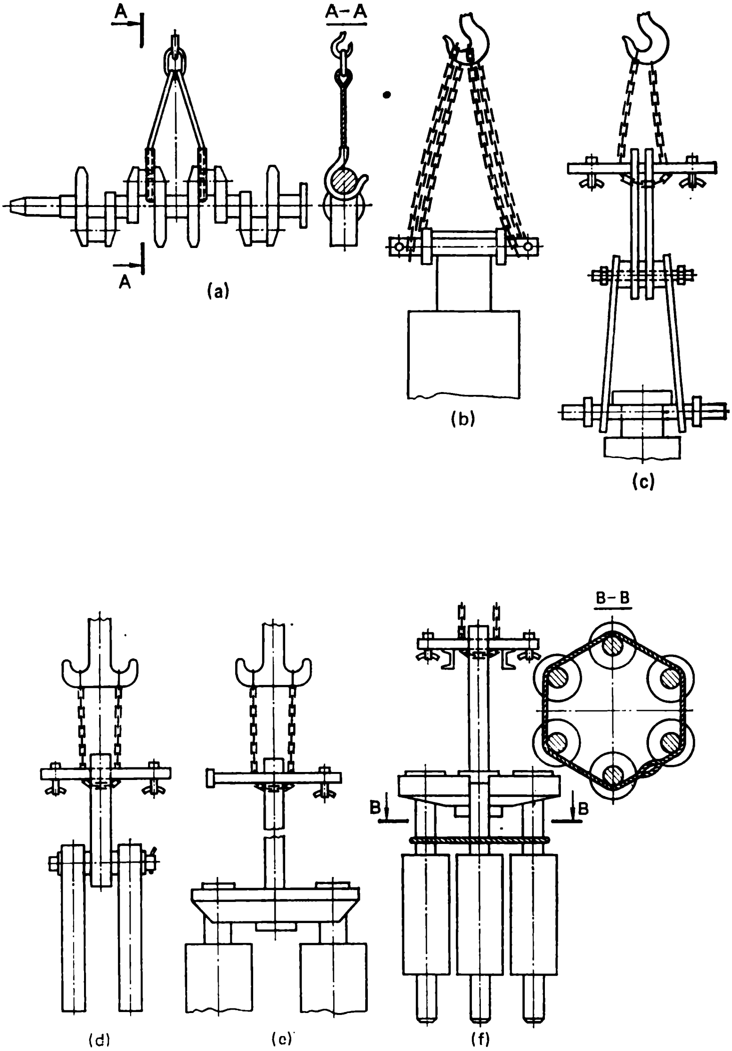

Fig. 55. Slinging of shaped shafts by special attachments: *a*—slinging by armoured slings and hooks with protective tubes; *b*—slinging by yokes; *c*—slinging using shackles and a yoke; *d*—slinging using a bar and a shackle; *e*—group slinging using spider for two shafts; *f*—group slinging using a spider for six shafts

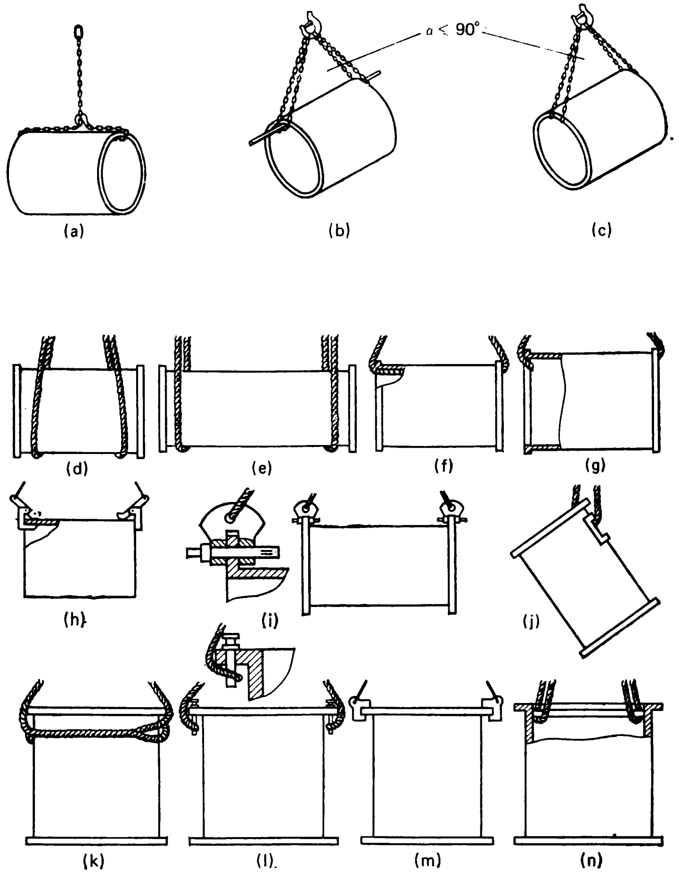

Fig. 56. Slinging of drums and shells:
a—slinging by a single-leg chain sling using a loop and hook; *b*—slinging by two endless slings using a special marked bar; *c*—slinging by an endless sling passed through the drum; *d*—slinging by simple envelopment; *e*—slinging with two slings for transportation by two cranes; *f*—slinging with a single-leg sling by simple envelopment through the drum; *g*—slinging by cross-members; *h*—slinging with an eccentric grip; *i*—slinging by stirrups with a pin; *j*—vertical sling by way of simple envelopment by the item window; *k*—vertical slinging with the use of a double running knot; *l*—vertical slinging with the use of pins; *m*—vertical slinging by a flange with the use of cramps; *n*—vertical slinging by a drum cross-member

double running knot and also through the use of pins. Slinging of drums by the flange with the use of cramps is very reliable. Drums with center cross-members are slung with general-purpose or light-duty slings by the cross-member, the sling loops being located on the sides. Shells without flanges are slung in the vertical position by eccentric grips. Since the majority of drums are more than 3-5 m in height they are tied using standard ladders. It is prohibited to use improvised supports for this purpose.

If gears, rims, pulleys, flywheels, shrouds have spokes and holes, the latter are used for slinging. Spokes are used to advantage for slinging parts in the horizontal position by means of a light-duty sling (Fig. 57*g*), a group sling with hooks (Fig. 57*h*), etc. If the number of spokes is even the item is slung by two legs and if the number of spokes is odd it is slung by three, four legs.

Should items have holes, rockers are used for their lifting (Fig. 57*j*). It is not recommended to convey such components by the central holes since they can be hardly balanced during transportation. Rings, sleeves, shrouds having neither hubs nor spokes are slung with two or three legs using a running knot or by double envelopment of the rim. Before transporting the item, it is obligatory to check it for equilibrium. While conveying in the vertical position the items with holes and spokes, use can be made of light-duty slings (Fig. 57*b* and *c*) or rockers (Fig. 57*e*), and while slinging sleeve-type items use is sometimes made of a running knot (Fig. 57*d*). Slings of hemp or polymer materials are employed for conveying light but bulky items.

Sleeves, rims, and the like items are advisable to be brought to machine tools using special hooks (Fig. 57*i* and *h*). Such method of transportation is productive, convenient and steel ropes are not wasted. Tapered gears are slung by hooks (Fig. 57*j*) and the blanks of spur pinions are conveyed with the aid of cramps (Fig. 57*k*). Figure 57*l* illustrates a slinging of a wheel by means of a tongs-type attachment.

If the item has nothing to be gripped but a center hole, tongs are used (Fig. 57*m*). The tongs levers spread when the slings are tightened and hold the item tightly. The

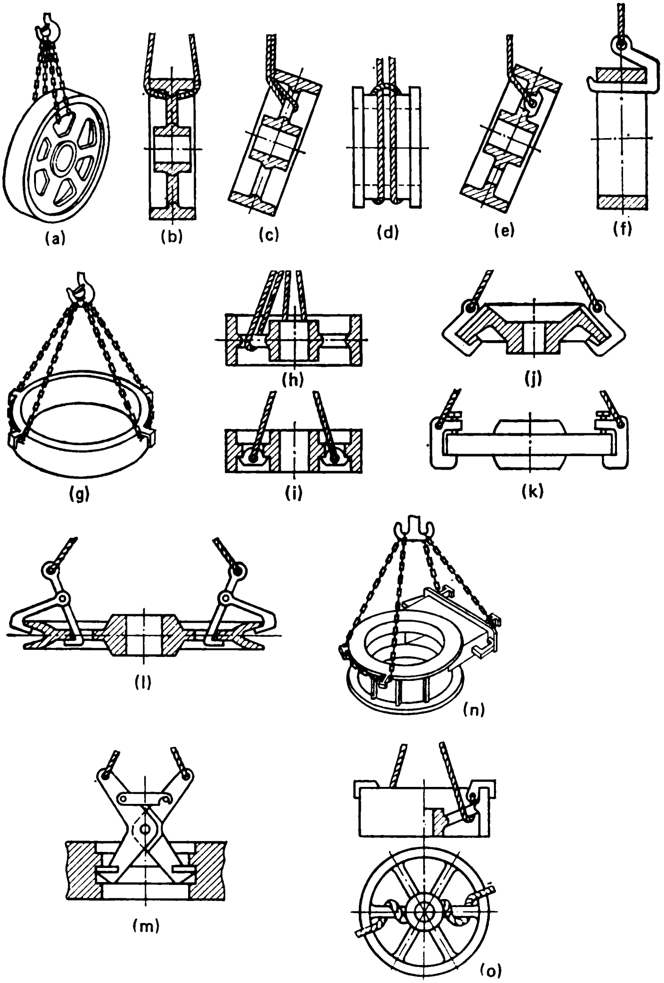
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Fig. 57. Slinging of items of drum, shroud and wheel type: *a*—slinging a pulley by a rim using an endless chain sling; *b*—the same but using a light-duty rope sling; *c*—slinging by a spoke using an endless light-duty rope sling; *d*—slinging a flanged sleeve using a general-purpose sling enveloping the sleeve body with a running knot; *e*—slinging a pulley by a spoke with a hole using a single-leg sling with a rocker; *f*—slinging a sleeve by a fork pickup attached to a single-leg sling; *g*—slinging a band by bosses using an endless chain sling; *h*—slinging a pulley with asymmetrically arranged spokes using two light-duty slings; *i*—slinging a pulley with symmetrically arranged spokes with holes by a two-leg sling with rockers; *j*—slinging a tapered gear in horizontal position by a two-leg sling with hooks; *k*—slinging a wheel in horizontal position by the rim using a two-leg sling with cramps; *l*—slinging a spoked wheel with holes by special tongs; *m*—slinging a machined item with holes by the groove in the hole using tongs; *n*—slinging a shroud by two endless chain slings; *o*—slinging a spoked pulley using light-duty slings with hooks

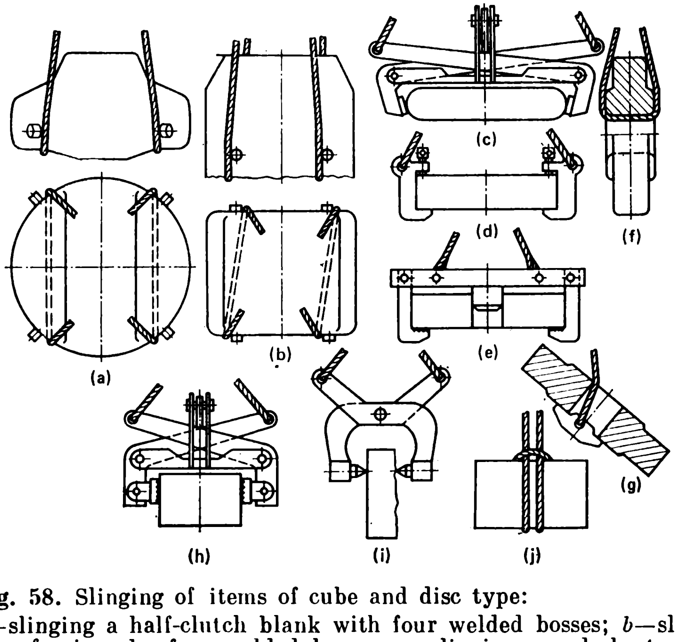


Fig. 58. Slinging of items of cube and disc type:
a—slinging a half-clutch blank with four welded bosses; *b*—slinging forgings by four welded bosses; *c*—slinging round short-cut blanks by tongs; *d*—the same but by cramps; *e*—slinging round articles with a central hole in horizontal position by a hooked beam with a central rod; *f*—slinging round items with a central hole in vertical position by a light-duty sling through envelopment; *g*—slinging round items by a single-leg sling with a rocker; *h*—slinging cubic items by tongs; *i*—slinging flat items by tongs; *j*—slinging flat items by enveloping with a light-duty sling

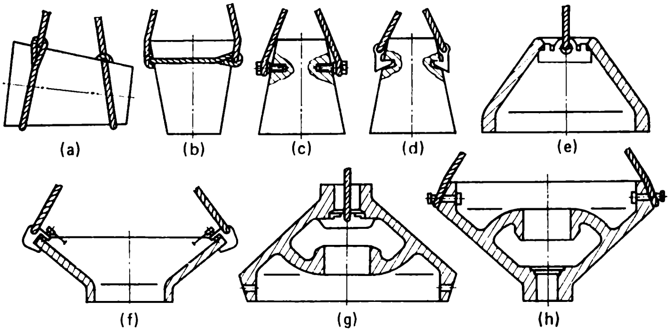


Fig. 59. Slinging of cone-shaped items: *a*—slinging items in horizontal position by light-duty rope slings by enveloping the load at two points; *b*—slinging items in vertical position by binding with a double running knot; *c*—slinging items with holes using pins; *d*—the same but using hooks; *e* and *g*—slinging a housing with a central hole using a rocker; *f*—slinging a housing with a cone down by means of cramps; *h*—the same with a hole using pins

item stability during transportation is achieved by adjusting the width of jaws within a 50-70 mm range by welding different straps to the grip. The lever positions are fixed by a collapsible hook which insures a safe transportation of the load.

The difficulty in slinging *cubes and discs* resides in the fact that they have no special points for gripping (Fig. 58). For instance, a half-clutch blank weighing 5 tonnes can be slung after welding four bosses spaced along the circumference so that they prevent the sling from slipping off the item. The same method is used for slinging the forgings weighing up to 20 tonnes. Since during the hoisting the slings can slip not only outwardly but inwardly as well they are to be applied along a diagonal with reference to the bosses. Light-weight items and end cuttings of components having no holes are slung by tongs or by cramps.

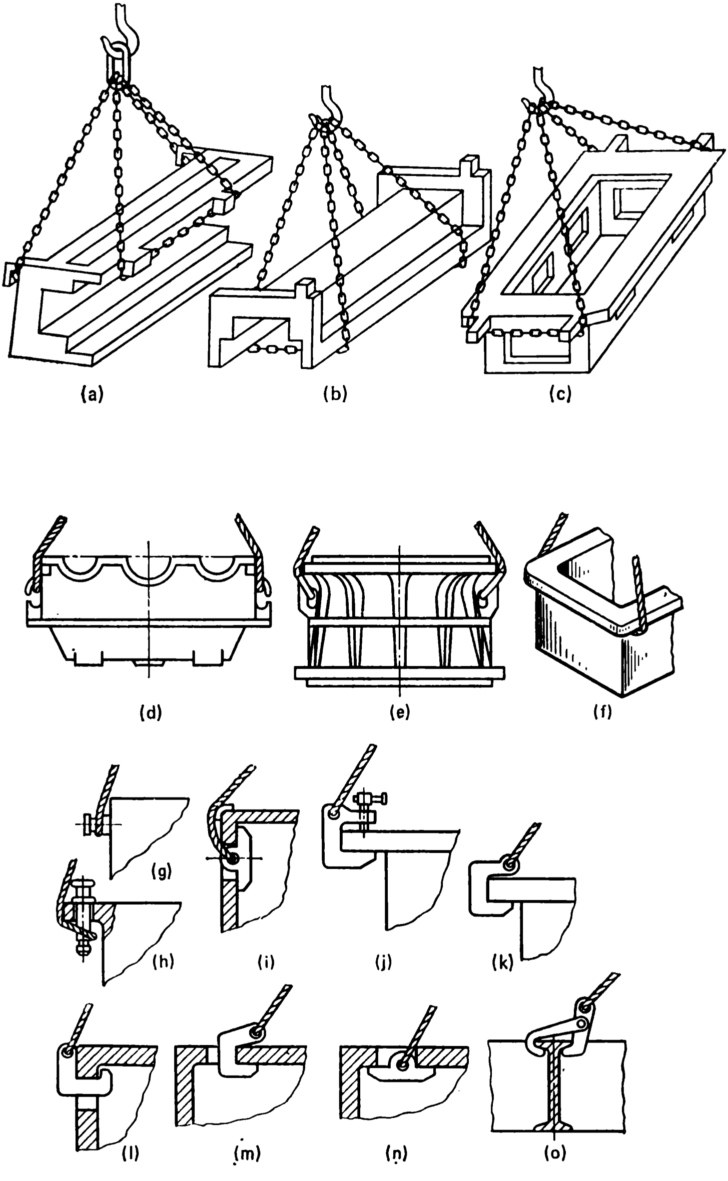
While slinging horizontally the items having a center hole, use is made of a hooked beam with a rod or a rocker. Such items are slung and moved in the vertical position by an ordinary sling. If there are no gripping appliances, cubes and prisms of greater sizes are allowed to be slung by means of an all-purpose sling using a slip knot.

To sling and move *cones* such as a housing of cone-shaped crusher in the horizontal position (Fig. 59*a*) use is made of a light-duty sling by enveloping the item at two points. To prevent the cone from slipping off, the low line of the cone contour is to be located horizontally which is adjusted by the length of the slings. Movement of this cone tied up by a double running knot in the vertical position is shown in Fig. 59*b*. Cones having holes for gripping are slung with the use of pins (Fig. 59*c*) or hooks (Fig. 59*d*). A cone having a central hole is moved with the use of a rocker (Fig. 59*e*). Movement of these parts with the cone down is carried out with the use of cramps (Fig. 59*f*) or pins (Fig. 59*g* and *h*). In the majority of cases cone-shaped parts are slung by means of light-duty slings with an obligatory use of standard gripping appliances.

Housings and frames are slung by the permanent places for hooking: hooks, ears, eyes, etc. (Fig. 60). Housings in an ordinary operating position are to be slung by two legs and if such items are transported upside down they are to be slung by four legs since in this case the center of gravity of the item is higher than the hooking points and the item is unstable. Flanged housings are slung by general-purpose or light-duty slings, cramps, tongs or by hooks and if the flanges have holes pins are used. Pins are also employed if the housing is provided with holes for them. Housings and frames with holes are slung with the use of rockers or hooks. Frames built up of shaped metal can be gripped with tongs which correspond to the metal shape.

Review Questions

1. How are shafts slung?
2. How are drums slung?
3. What is the way of slinging the parts of gear, ring and pulley type?
4. How are cubes and discs slung?
5. How are cone-shaped items slung?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6.4. Slinging of Equipment and Frame Components of Machine Tools

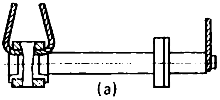
Slinging unique components (frames of rolling mills, cross-pieces of powerful presses and crushers and other parts weighing more than 75 tonnes) is sometimes simple but labour consuming due to their great weight. Very heavy items are slung with steel ropes 50-65 mm in diameter having several legs and they are usually hoisted by two cranes. A rolling mill frame (weighing 136 tonnes) in its usual position is slung with a steel rope 62 mm in diameter having eight legs whose four legs embrace the neck and the remaining legs embrace the trunnions (Fig. 61). Chamfered bushings which serve as spacers under the slings are inserted into the frame neck from two sides. To prevent the spacers from falling out during lifting or tilting, they are attached to each other. The item is transported by two cranes.

If the frame is slung with the help of a rocker, the stirrups are welded to the rocker for centering the slings. To reduce the bending moment of the rocker a spacer ring having an inner diameter less than the neck diameter is placed under it.

Unique items must be slung, conveyed and tilted according to the technological procedures developed by an experienced slinger beforehand under direct supervision of engineers.

Machines and equipment are to be slung by the most reliable places and first of all by special grippable ap-

Fig. 60. Slinging of housings and frames:
a—slinging by bosses using an endless chain sling; *b*—slinging by enveloping with two endless chain slings; *c*—slinging by end face bosses using endless chain slings; *d*—slinging by bosses using light-duty slings with loops; *e*—the same but with hooks; *f*—slinging by flanges using an endless light-duty sling; *g*—slinging by trunnions using a rope sling; *h*—slinging by pins; *i*—slinging a housing with side pockets using a light-duty sling with a rocker; *j*—slinging by a flange using a light-duty sling with cramps; *k*—slinging by a flange using a multi-leg sling with hooks; *l*—the same but by a side window; *m*—the same but by the upper window; *n*—slinging a housing by the upper window using a multi-leg sling with a rocker; *o*—slinging by a stiffening rib using a multi-leg sling with a special tongs-type grip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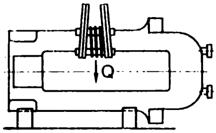

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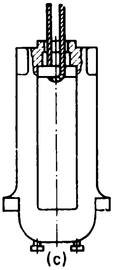
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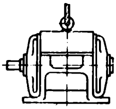
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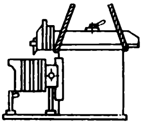
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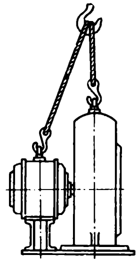
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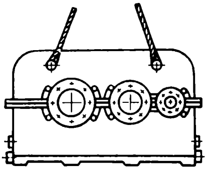
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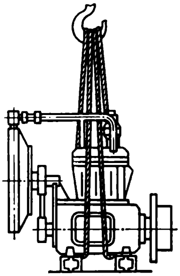
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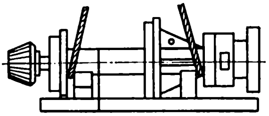
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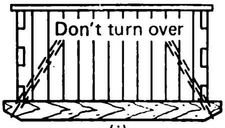

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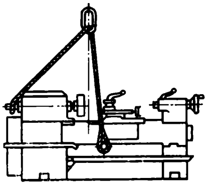
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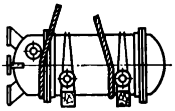
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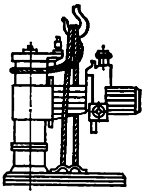
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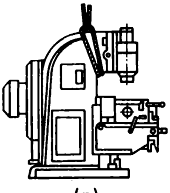
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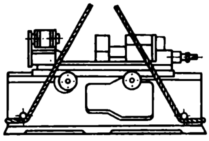
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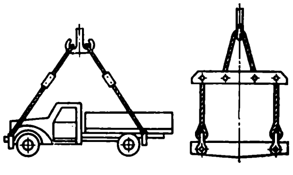
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pliances: ears, hooks, trunnions, eyes, etc. If several mechanisms are assembled on one frame, the entire assembly is to be lifted by catching this very frame. While slinging machines and equipment, special attention must be paid to their stability and equilibrium during hoisting, transportation and mounting. Machines and equipment provided with instructions and certificates in which the places of hooking are indicated are slung in accordance with the prescribed technology.

Electric motors, reduction gears, fans and other assemblies, machines and equipment provided with eyes, ears, trunnions are slung by these appliances with the use of light-duty or group slings (Fig. 61*d* through *j*). While hoisting a fan mounted on one frame with the electric motor, the main sling is to be attached to the fan and the auxiliary one to the electric motor in order to balance the load.

A transverse planing machine is slung by its slide (Fig. 61*e*). The machine tied up in this way is well balanced and the slide, being a reliable component of the machine, insures safe hoisting of the load. While slinging a lathe the main sling with a rocker sunk under the machine frame is secured to the point slightly shifted from the center of gravity to the right towards the tail stock and the additional sling is attached to the head stock hooking the extending portion of the spindle or a pin inserted into it.

A compressor weighing 900 kg is slung by its base according to the center of gravity using two light-duty slings (Fig. 61*h*). Since the center of gravity of the machine is much higher than the place of attachment, it is dangerous to transport it in such a position: the load is

Fig. 61. Slinging of equipment, machine tools and assemblies: *a*—slinging a rolling mill bed in horizontal position; *b*—the same but by the post; *c*—slinging a rolling mill bed in vertical position; *d*—slinging an electric motor by an eye; *e*—slinging a planing machine; *f*—slinging a reduction gear complete with motor by eyes; *g*—slinging a reduction gear by trunnions; *h*—slinging a compressor; *i*—slinging a driving shaft; *j*—slinging a container on a pallet; *k*—slinging a turret lathe; *l*—slinging a cooler filter; *m*, *n* and *o*—slinging the drilling, milling and grinding machines; *p*—slinging a truck using a load beam

unstable, therefore the top of the compressor is securred to the legs of the main sling by means of an additional sling. An additional sling is to be used in all the cases when the load is unstable and when it is impossible to attach the load higher than its center of gravity (Fig. 61*h* and *k*).

Cylindrical articles, such as the driving shaft of a crusher (Fig. 61*i*) and a cooler filter mounted on flat cars together with wooden frame-spacers are slung with light-duty or general-purpose slings by simple envelopment or by a running knot right to the item.

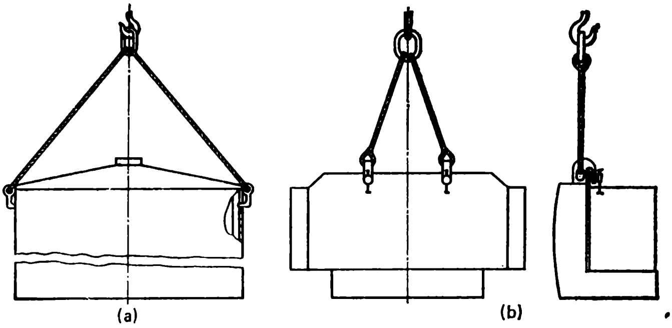

Fig. 62. Slinging of a fuel tank (*a*) and a tractor radiator (*b*)

Packaged machines and equipment (Fig. 61*j*) are slung by the frames of the package through envelopment with general-purpose or light-duty slings. In the majority of cases the package frame suffers little from bending force since it takes up the load together with the goods in the package and therefore is subjected mainly to compression. The package often bears the marking which indicates the center of gravity, the points of slinging, the net and gross weight of the package.

Machines and machine tools are the most diverse kind of materials therefore they are slung by general-purpose slings. They are used for lifting drilling (Fig. 61*m*), milling (Fig. 61*n*), grinding (Fig. 61*o*) and other machines. However, while disassembling the machines in some cases it is advisable to use special slings (Fig. 61*p*).

Figure 62 illustrates slinging of a water radiator of a tractor with the use of a group sling having special hooks inserted into the holes in the side walls of the radiator frame. A tractor tank is slung with a shackle-cramp (Fig. 62*b*). The cramp screw goes into the hole in the tank rib and reliably holds the unit. Slinging of such units with general-purpose and light-duty slings is not convenient and labour consuming, but slinging with the help of special grippers is simple, productive and safe.

To prevent heavy-weight machines and assemblies from damage during transportation by cranes and to facilitate the slinging, use is made of the load beams whose design is chosen depending on the size and weight of the load. An H-shaped load beam (Fig. 63) of 12 tonne capacity with two light-duty slings and four rectangular spacers may be employed for slinging a tractor weighing 11.5 tonnes as well as other machines and mechanisms. Such an appliance is useful and practicable for one-time and rare hoisting.

The mass and series production requires more specialized load-gripping appliances.

For example, at the Chelyabinsk tractor plant tractors are slung by the use of an appliance comprising a frame-

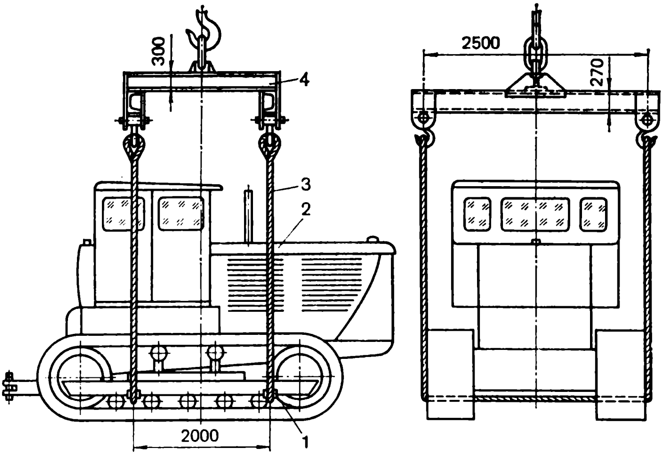

Fig. 63. Slinging of a tractor:
1—safety spacer; *2*—tractor; *3*—two-loop slings; *4*—load beam

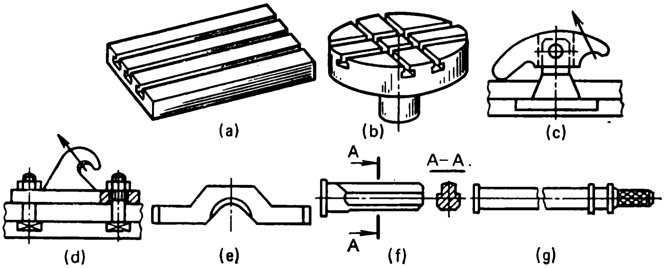

Fig. 64. Accessories for slinging machine tools and equipment assemblies:
a—portable table with T-shaped grooves; *b*—faceplate; *c*—pivotal gripper; *d*—cover hook; *e*—cover bail; *f*—pin-trunnion; *g*—pin-insert

shaped load beam whose corners are provided with chain slings terminating in special grippers. Using guy ropes and a shackle the beam is suspended from the crane hook and the grippers are secured to the track frames during tractor slinging. Such an appliance is more efficient than that described above but is more difficult in fabrication and pays off only in case of a mass production.

Some machine tools and assemblies have no suitable places for slinging, therefore in order to facilitate slinging a number of machine-building plants employ diverse auxiliary devices (Fig. 64). The drilling machine, for instance, is more convenient to be slung by bails attached to the T-shaped grooves of the table.

Slinging of the grinding machine becomes more practicable if pin-inserts are used (Fig. 64*g*). Units like a portable table (Fig. 64*a*) or a faceplate (Fig. 64*b*) of a machine tool are practically impossible to be hooked without special accessories: pivotal gripper (Fig. 64*c*), cover hook (Fig. 64*d*) or pin-trunnion (Fig. 64*f*) secured in T-shaped grooves of tables and faceplates. Auxiliary devices for slinging machines are made of various sizes and load-carrying capacity according to the same technical requirements as standard load-gripping means.

Units, machines and equipment must be slung carefully, without any hurry, checking the reliability of tying by trial lifts and additional inspections; one should always keep in mind that the load is a critical and expensive item which can be broken dead in case of an accident.

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Review Questions

1. What is the way of slinging a mill frame?
2. How is the electrical equipment slung?
3. What is the way of slinging machine tools?
4. How are individual units slung?

6.5. Slinging of Rolled Metal Products

Flexibility of sheet metal, absence of load-gripping appliances, and great area size are the factors which hinder the hoisting and movement of sheets by means of ordinary slings without specialized appliances. Group slings with hooks or snap hooks are suitable for slinging sheets to be lifted vertically (Fig. 65*a*). In such a method of tying the slings are prevented from sharp bending and deformation due to spacers. To provide a balanced and reliable gripping of the sheet, a spacer is inserted between the sling legs which does not allow the ropes to move closer or slip to some direction.

Metal plates more than 4 mm thick are slung with lever-eccentric clamps (Fig. 65*b* and *c*). Upon tightening of the sling legs the plate descends under gravity force and is automatically squeezed by the levers in the clamp. The lever clamping end is provided with a sharp serration which tightly holds the metal from slipping off. The number of legs and clamps of the sling is selected according to the size and weight of the load.

When the volume is not large and the load is conveyed piece by piece, load-gripping or ordinary locksmith's cramps are used instead of lever-eccentric clamps (Fig. 65*d*). Critical loads are not allowed to be lifted with the use of locksmith's cramps.

To convey sheet metal in stacks, grabs are used (Fig. 65*e*) which consist of four or six claws suspended from a load beam. The advantage of such grabs is a quick slinging, the disadvantage is a great weight of the claws. If the metal plates are stored one upon the other without any spacers they cannot be hooked by grabs. In this case the plates are raised before slinging by driving wedges between them.

Tubes and round bars of a small diameter are slung in bundles while heavy billets and tubes of a large diameter are slung piece by piece. To provide safety in transporting round bars and tubes in bundles, it is necessary that each bar or tube after gripping is tightly squeezed and a strictly horizontal position and minimum sagging are provided during hoisting. The balance is achieved

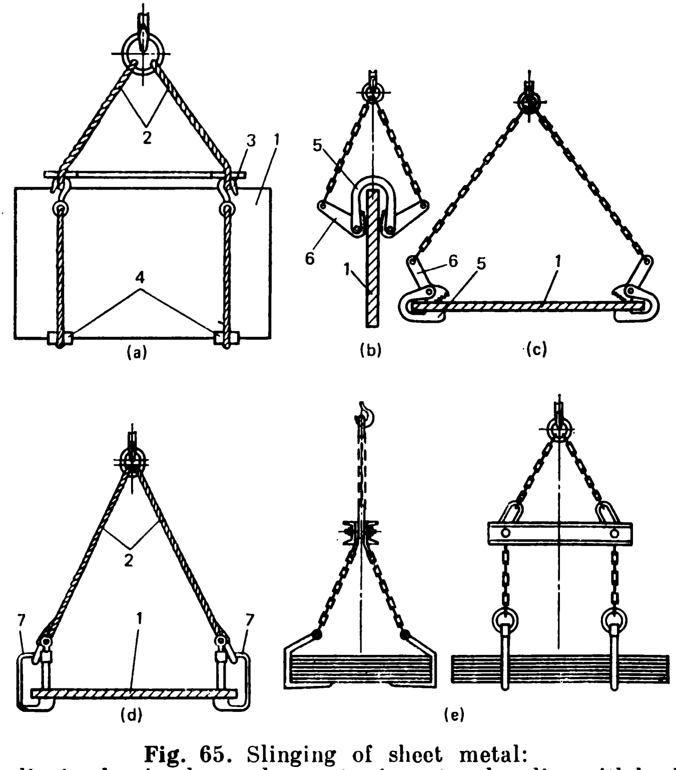


Fig. 65. Slinging of sheet metal:
a—slinging by simple envelopment using a two-leg sling with hooks and spreading rod; *b*—slinging with a two-sided eccentric clamp; *c*—slinging with a two-leg sling provided with a one-sided eccentric clamp; *d*—slinging using locksmith's cramps; *e*—slinging a sheet stack with grabs; *1*—sheet; *2*—sling leg; *3*—hook; *4*—spacer; *5*—bail; *6*—tightening lever; *7*- locksmith's cramp

by tying up the bundle at two or more places, the grips being located symmetrically.

At works round bars and tubes are to be slung by means of tongs or grabs. Paired tongs (Fig. 66*a*) quickly pick up and release the load to be handled. While grabbing with tongs the articles are not obligatory to be piled on pallets. Wide use is made of beams with slings and hooks (Fig. 66*b*).

Round bars and tubes are most frequently slung with general-purpose and light-duty slings by tying them up through the use of a builder's loop (Fig. 66*c*). Although the slinging in this way is simple and safe it is not productive.

Thick short tubes and billets are sometimes advisable to be transported in the vertical position for technological reasons. To sling cylindrical loads, a special gripper is used (Fig. 66*d*). It comprises a beam with flexible rope

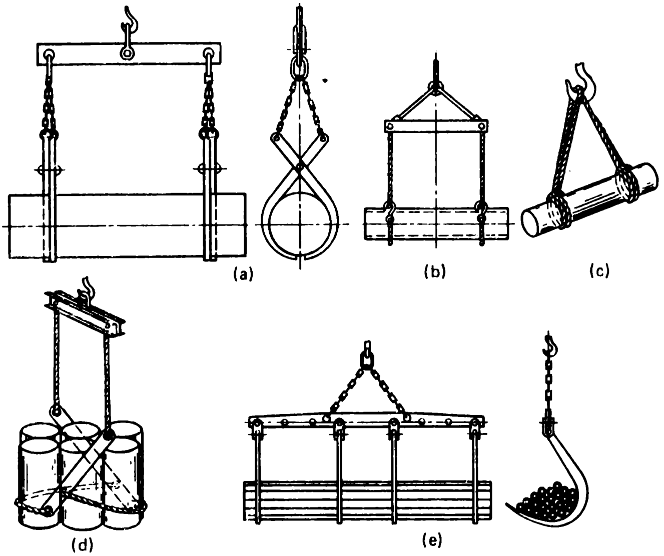


Fig. 66. Slinging of round-shaped rolled products and tubes: *a*—slinging with tongs attached to a load beam; *b*—slinging using a beam with slings and hooks; *c*—slinging with a general-purpose sling using a builder's loop; *d*—slinging with group slings attached to a load beam; *e*—slinging using a load beam with four claws

suspensions and two rocking levers connected to two flexible rope loops. In the course of attachment, the loops are fitted onto the load and during hoisting the rocking levers turn and flexible loops bind the grip. Using such a gripper the items can be transported in the vertical position by single units and in small groups.

To hoist tubes and round bars in bundles, an open side grab is used (Fig. 66*e*). It includes a beam and two or more claws pivotally connected to the beam. Depending on the length of the load to be lifted the claws can be located at different distances from each other. A bundle of metal prepared for lifting by means of the open side grab is preliminarily piled on the pallets of such a height that the grab claws can be brought under it. Care and attention must be taken in lifting and moving loads with the help of an open side grab since in case of great swinging the load can slip off the grab.

Short-cut tubes and billets are allowed to be lifted by one sling using a slip knot, but two or more slings are to be used for heavy-weight and long loads.

While slinging *rolled products* (angles, channels, T-beams, rails, etc.) use is made of general-purpose, light-duty, semiautomatic slings, tongs and grabs. While tying up rolled products by means of rope slings spacers are inserted under their sharp corners (Fig. 67*a*).

Large-size rolled products are more convenient to be moved by means of tongs with the jaws which correspond to the product shape (Fig. 67*b* and *c*). Long-cut rolled stock is allowed to be lifted only by means of paired tongs. While grabbing the load at one point it may slip off the grab or the grab lever may break down.

Rolled stock is used for building various structures which differ in weight, shape, size and method of piling. However, the slinging technique for handling absolutely different metal structures may be the same. Figure 67*d* illustrates the tying of A-frames of a power transmission line support. The A-frames are piled to form a bundle *2* and the bundle is tied with wire *1* to prevent it from scattering. Since the A-beams are not long the bundle can be hooked with light-duty sling *3* at one point by catching cross pieces which correspond to the center of gravity of the load.

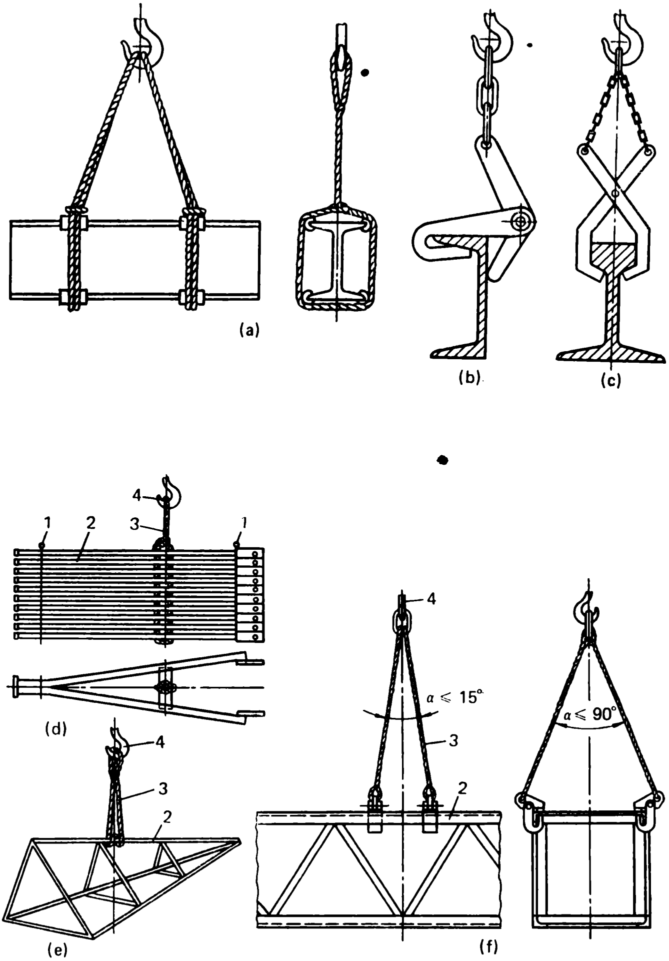


Fig. 67. Slinging of trusses and rolled products: *a*—slinging an I-beam using light-duty slings by enveloping; *b*—slinging a channel using special tongs; *c*—slinging a rail with tongs; *d*—slinging a bundle of A-frames by embracing their cross pieces; *e*—slinging a pyramidal structure by double embracing of the main chord; *f*—slinging a rectangular truss using a group sling with special grips; *1*—tying wire; *2*—bundle of metal structures; *3*—sling; *4*—hook

Light-duty slings fabricated of steel ropes possess a number of advantages: they are light-weight, flexible, etc., but they quickly wear out as a result of severe bending at the corners of metal structures.

To sling light and heavy metal structures, a combined sling is better to be used (Fig. 67*e*). The sling runs twice over the main chord of the structure, embraces it tightly and therefore it does not slide over the structure.

To transport rectangular structures made of steel angles, it is more advantageous to use group slings provided with special grips (Fig. 67*f*). Such grips are simple in fabrication, have a long service life, tightly hold the load, practical in operation, can hook both large and small angles.

Review Questions

1. What are the peculiar features of slinging sheet metal?
2. What are the peculiar features of slinging round bars?
3. What is the way of slinging rolled stock and items made of it?

6.6. Peculiarities of Slinging Dangerous Materials in Metallurgical Practice

In metallurgical practice the majority of loads are referred to as dangerous ones (molten metal, hot ingots, molten slag, etc.) therefore measures are taken to prevent man from direct contact with the load. Wherever possible manual slinging is replaced by an automatic slinging. Slinging dangerous loads in practice reduces to attaching the load-gripping device to a crane hook and connecting various lines needed for work (electric cable if electromagnets are used, pneumatic hoses for vacuum lifters, etc.).

Another peculiar feature of the metallurgical practice is the fact that the main operating personnel (steel-maker and his assistant, etc.) are continuously engaged in slinging. All the shift long they receive various materials and tap molten metal into the ladle. Steelmakers and their assistants always deal with load-gripping devices attached to a crane, steel ropes and chains, and with different slinging appliances. The same can be said about the workers who attend rolling mills, blast furnaces and other workshops.

Load handling attachments used in open hearth workshops comprise one-piece forged hooks (small drafts of the cranes) or laminated ones, stamped hooks thermally treated (main drafts of the cranes). The hook surface must be smooth without any cracks. The factor of safety of the hook for lifting and moving ladles with molten metal should be 12.

Hooks with a lifting capacity above 3 tonnes must be made rotatable in closed ball supports except the hooks for casting cranes. The hook is suspended so that it is easily mounted and free to rotate during operation in accordance with the load position.

It is difficult to detect latent flaws in forged and stamped hooks designed for a great lifting capacity therefore the hooks for lifting ladles with molten metal are fabricated by riveting a number of plates of sheet metal. In such a structure a breakage of the entire hook is hardly possible and a failure of one of the two plates is easily found and removed. All the hooks have a mouth wide enough to house ropes and chains by which the load is suspended. The top portion of the forged hook rod has a triangular thread for hooks with a lifting capacity above 10 tonnes. This thread receives a nut which is secured so that it cannot get loose or unscrewed in the course of lengthy operation. A cotter pin or a stop plate is used for this purpose. The nut lower surface rests against the upper case of the thrust ball bearing. The Manufacturer's marks indicating the lifting capacity are stamped on all hooks.

For transporting loose materials (coke, coal, lime, limestone, sand, clay) by means of a bridge crane use is made of clamshells. A simplest clamshell is a steel bucket cut into scoops rotatable about pivots secured to the clamshell head by means of links. When the rope tension is eased off the beam goes down under gravity due to which the clamshell scoops get opened. In such a way the clamshell is lowered down onto the material. Then the rope is tightened up and the scoops get closed gripping the load. The clamshell construction must prevent spontaneous opening of the bucket scoops.

To move metal, electromagnets with mechanical grabs are used. While moving metal heated to 300 °C the lifting capacity of electromagnets remains unchanged and is getting smaller at 600-700 °C only. In handling hot metal the electromagnet itself gets heated and its lifting capacity quickly decreases due to which the load lifted by the crane may break away; therefore intervals are to be made during operation to let the electromagnet cool down. The main disadvantage of an electromagnet resides in the fact that its lifting power vanishes in case of no power supply, short circuits or damage to the wires. Therefore there should be no people and equipment along the electromagnet path. To insure reliable operation of an electromagnet, it is made with a double wiring so that disconnection of one of the circuits does not lead to the load fall.

At storage areas of finished products use is made of only rectangular magnets equipped with mechanical grips for stockpiling metal items especially if they are longer than 4 meters. Special cranes servicing heating pits of rolling mills are provided with load-gripping mechanisms (tongs). Tongs are outfitted with spikes made of special steel and faced with hard alloy. For safe loading of ingots by means of stripping cranes use is made of a tongs-type grab comprising two beams, tongs and a center bolt rotatable in thrust bearings secured to the beams. While using the grabs special attention is to be paid to the bolt joint since if the nut is unscrewed the load will fall down in the area where people are working; a failure of the tongs at the moment of load lifting is also dangerous for men working under the crane.

In ferrous metallurgy a number of slinging devices are used (Fig. 68). The slings in operation are provided with tags indicating the number, date of the test and a permissible lifting capacity. All the slinging devices are to be inspected at least once in 10 days by a person responsible for their servicing; every six months they are tested under the load which is twice the nominal load.

For slings designed for lifting a particular type of items the real angle of spreading may be taken into consideration. While calculating slings designed for

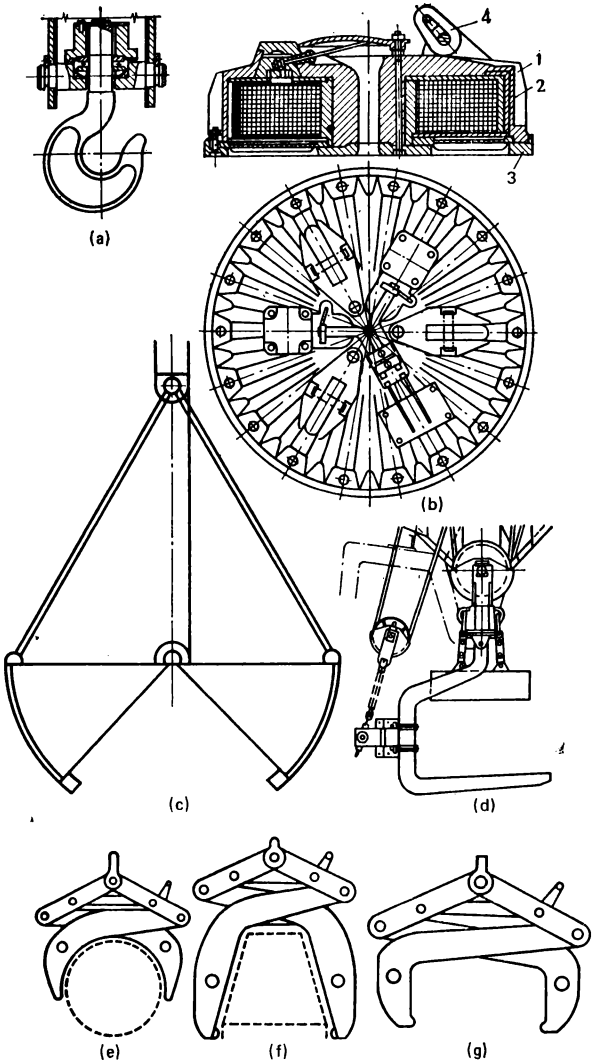


Fig. 68. Types of materials handling attachments: *a*—hook-type attachment; *b*—lifting magnet; *c*—clamshell; *d*—grabs; *e*, *f* and *g*—tongs-type grabs for shafts, ingots, and rolls, respectively; *1*—case; *2*—electromagnet; *3*—base plate; *4*—shackle

lifting a load with tying up or hooking the factor of safety of the rope must be not less than 6. The structure of multi-leg slings must insure a uniform tension of all the legs. In moving the loads with sharp edges soft spacers or special angles are to be placed under the rope slings.

For suspending loads in ferrous metallurgy use is made of usual welded non-calibrated chains with rings and hooks. The use of chains with elongated links is prohibited. The factor of safety for welded sling chains terminating in any gripping appliances must be more than 5, and that for the chain slings designed for binding the load, not less than 6. The tolerable wear of the welded chain link is not more than 10% of its initial diameter. After new links have been inserted, the chain, if it is not designed for moving ladles, is tested under the load which is 1.25 times greater than the rated lifting capacity; the chain is kept loaded for 10 minutes. Chain slings are used more seldom than the rope ones since they are heavier and their fabrication is more labour consuming, however, chain slings are often used for transporting hot red materials.

Widely used in ferrous metallurgy are special beams for transporting various loads. For instance, load beams are employed to convey slag buckets in steel making practice. Beams are also used for transporting intermediate ladles and split runners. The use of special load beams insures safety in transportation of heated equipment.

Development and employment of various slinging devices is aimed at providing a reliable and quick gripping of various items and preventing the load from breaking down during transportation. Practically all the items conveyed in metallurgical practice are provided with gripping appliances and are simple for slinging by corresponding devices. Baskets and self-discharging boxes are provided with trunnions or ears to capture them with slings. Moulds have two pairs of trunnions for their tilting and transportation.

Boxes for charging materials into melting furnaces are often slung by four-leg slings with hooks. Slinging is carried out on a platform and then the boxes are delivered to the furnace bay. To place charging boxes, racks are mounted on the furnace bay balcony. If charging boxes are transported by means of cranes using chain slings with hooks, the width of the racks must be not less than the length of the charging boxes. If the charging boxes are transported by cranes with mechanized grips, the width of the racks is determined by the conditions of catching the charging boxes with frames. The charging boxes are placed on the racks without any overhangs and skewness.

In workshops with floor charging machines bulk materials are delivered, as a rule, to the operating area of the furnace in special bunkers having grippable appliances.

Review Questions

1. What are the peculiarities of materials slinging in metallurgical practice?
2. How are bulk materials transported?
3. How is molten metal transported?

Chapter VII

Tilting of Materials

7.1. General

Tilting is an operation aimed at changing the position of an item by turning over. In metallurgical practice tilting is used for pouring metal from furnaces into ladles, from ladles into mixers, furnaces, moulds, etc. At machine-building practice tilting is necessary for changing the machining steps. Items are tilted in repair, mounting and dismounting of the equipment. Sometimes the load is tilted when the item is to take a required position, for instance in changing over the equipment from travelling to operating position and vice versa.

In the process of production, parts and units are often repeatedly tilted: during forging, machining, hydropneumatic cleaning, etc. Depending on the workshop area, its equipment, the shape and weight of the component, the number of items produced different kinds of tilting are resorted to.

Manual Tilting

Components weighing up to 100 kg are tilted by means of a pinch bar and blocks (Fig. 69*a* and *b*) for which purpose first a bent portion of the bar is inserted under the

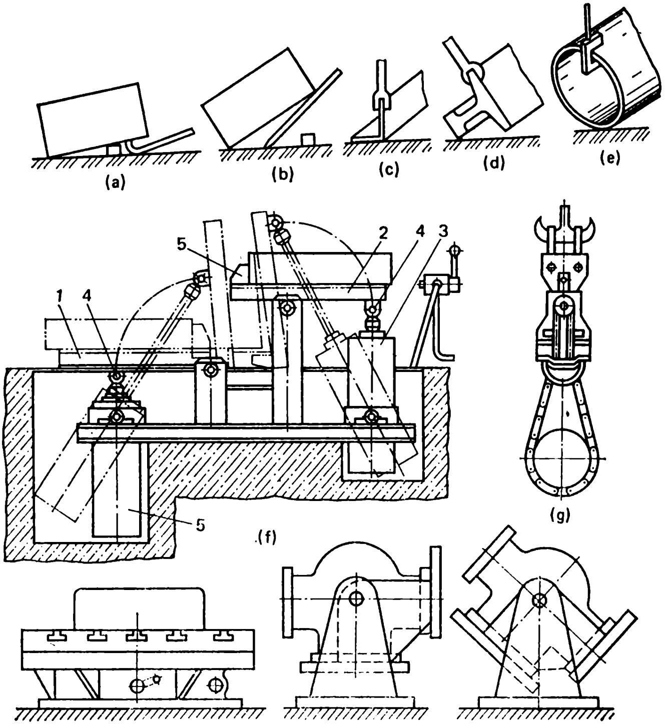


Fig. 69. Tilting of items:
a and *b*—tilting a rectangular item by means of a pinch bar; *c*, *d* and *e*—tilting rolled shapes and tubes by means of a tilting wrench; —pneumatic tilter; *g*—crane-mounted rotatable suspension; *h*—suspendable tilter with an electric motor; *i* and *j*—arrangement for tilting items through 90°

item, the item is lifted and a block is placed under it, then the item is turned over with the use of a straight portion of the pinch bar. Shaped large-size metal (angles, channels, rails, etc.) can be tilted by means of a special tool which looks like a wrench (Fig. 69*c* through *e*). Manual tilters (gripping levers) are often used for turning items and units when they are being lifted not manually but by cranes.

Tilting of Items by Mechanisms

Items weighing more than 100 kg are turned over by special mechanical tilters. The items are turned about the longitudinal horizontal axis by means of chain tilters which are suspended from crane hooks; and by tongs-type tilter-manipulators which have found wide use in press forging and in arc-welding operations. The items are turned about their vertical axis with the help of rollers, carts, turntables, tables of machine tools, etc. Uralmash plant employs turntables with a carrying capacity of up to 100 tonnes for turning (shifting) parts about their vertical axis (Fig. 69*g*).

The design of mechanical tilters is different. A tilter (Fig. 69*f*) designed for turning over flat blanks comprises two rocking tables *1* and *2* and two pneumatic cylinders *3* pivotally secured to the frame. The tables are connected to the cylinder rods by means of axles *4*. With both cylinders operating, the component placed on table *2* is turned approximately through 95-100° (it is shown in the figure in fine lines) and is thrown onto table *1*. In the vertical position it is held by stops *5*. When the tables return to their initial position the component will remain on table *1* upside down. Figure 69*h* illustrates an ordinary turntable mounted at or on the machine tool. A component placed on it by a crane may be turned through any angle in the horizontal plane.

A very simple device (chair) for tilting not heavy items through 90° is shown in Fig. 69*i* and *j*. A component is put onto the tilter so that it thrusts against the vertical wall of the rocking angle which is turned manually by hand together with the component. The component weighing up to 200 kg and the handle length being 250 mm, the effort to be applied for rotation is not more than 50-60 N.

A chain electric tilter (Fig. 69*g*) is designed for tilting parts weighing up to 200 tonnes. An endless roller chain of the tilter is driven by an electric motor through a reduction gear and is rotatable at a rate of 6-9 m/min. Paired tilters attached to crane hooks by means of bails can turn and transport parts from one machine tool to the other, i.e. they can be used as load-gripping devices.

To tilt parts of series and mass production, special tilters are to be installed in the production line. In individual production tilting equipment is more expensive since it is used for a short period of time. It is more advantageous to turn over single large-size items on tilting grounds.

Tilting of Materials by Cranes

Tilting by cranes is a critical and labour-consuming operation which can be accomplished only by experienced and skilled slingers and crane operators. Tilting or changing the position of some sophisticated equipment takes sometimes from several hours to full time of the shift and even longer. Therefore, proper organization and selection of the most effective method of tilting have a particular effect on labour productivity of machine tool operators and the factor of the equipment utilization. The parts can be tilted by one crane and by two paired cranes operating on one rail track or on different ones, and sometimes one above the other which is a usual practice in modern workshops having a high ceiling.

In the process of turning over the position of the center of gravity of the item is very important. When it is within the limits of the support area (Fig. 70*a*, position I), the item is at rest. At the moment of lifting when the center of gravity goes beyond the support area (position II) the item turns over and falls upon the other plane (position III). Therefore, the tilting is based on the principle of a forced shift of the center of gravity.

The tilting can be accomplished smoothly, by jerks or with impacts. This depends on the location of the point used for load hooking, the number of sling legs and the number of points of load attachment. Tilting of a load

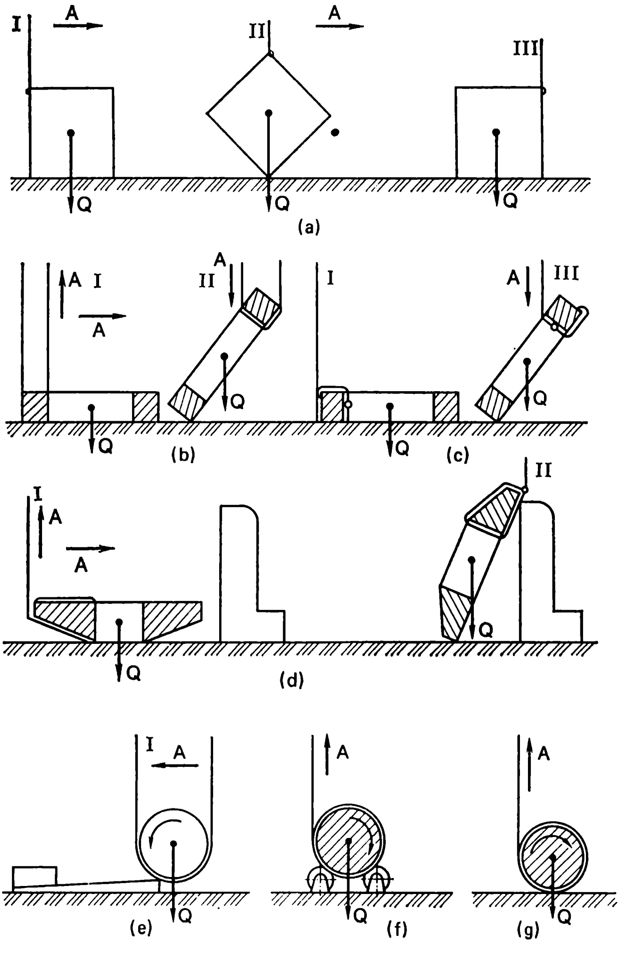


Fig. 70. Free tilting of items:
a—tilting an item secured in the upper point; *b*—tilting by simple envelopment in the upper point; *c*—tilting by a hook applied to the upper point; *d*—tilting high and unstable items by means of an angle member; *e*—tilting items of shaft and drum types over a slant surface to the stop; *f*—tilting by rotation in roller prisms; *g*—tilting on a surface (I through III—positions of tilting)

hooked at the upper point (Fig. 70*b* and *c*) will be smooth, but if the load is hooked at the lower portion (Fig. 70*d*) the tilting will be with an impact since in this case the item is held by nothing and freely turns over. Actually, even if the tilting is smooth, jerks are sensed. This occurs due to the fact that during the turning-over of the item the slings are tightened in an inclined position. At the moment the load is tipped over they get slack and then are tightened again.

While tilting large-size items the amplitude of the free fall may be great, therefore, the jerks may be heavy. It is almost impossible to eliminate these jerks since the speed of load falling is much greater than the speed of movement of any crane mechanism.

Selection of the method of tilting depends on the weight and dimensions of the load, its configuration, availability of the places for gripping and possibility of attaching the slings. The methods which are most widely used are free tilting, tilting with a support and tilting with a kick.

Smooth turning-over of the load is called *free tilting* and turning-over involving a free fall is called *tilting with a kick.* The last method is very simple but not recommended for wide use since it is connected with a danger of hurting the personnel and with a possibility of damaging the items. The load is turned over by coordinated motions of the crane: by lifting and lowering the hook and by moving the bridge or the trolley. The turning-over itself is accomplished by driving the bridge or the trolley. The bridge movement is to be used to a limited extent and with a great care since at a slant tension the crane ropes slip off the winch drum grooves, chafe against the drum collars due to which the rope is heavily teased off and fails. Large-size items, such as rings, bands, gears, pulleys, are tilted freely suspended. The item in this case can be slung by simple envelopment (Fig. 70*b*) or by a hook (Fig. 70*c*). In the first case the load slides along the sling and severely rubs it off, while in the second case the sling does not slide but freely unreels from the load. Round items, such as drums and shafts, are turned over during their machining and painting by rolling them over a slant surface up to the stop (Fig. 70*e*), by

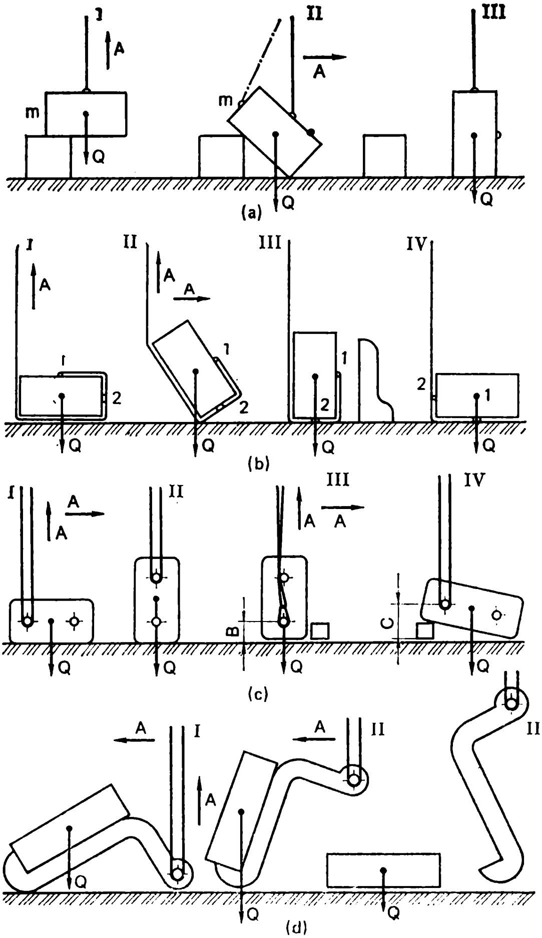


Fig. 71. Tilting with a support and with a kick: *a*—tilting with a support by reslinging the item; *b*—tilting by simple envelopment of an item using a safety angle member; *c*—tilting by placing the item on its end face, slinging by trunnions and changing the place of slinging; *d*—tilting with the use of L-shaped tilter

rotating them in roller prisms (Fig. 70*f*), or by rolling them over a flat surface (Fig. 70*g*). In the case shown in Fig. 70*f* the sling is wound about the item several times and the sling end is secured to the load, for the case shown in Fig. 70*g* the sling is secured by a running knot.

When high and unstable items are tilted and when reslinging is necessary use is made of angle members (Fig. 70*d*) which the load is leaned against and thus takes a stable position.

Tilting with a support is carried out in the following way. The crane lowers an item against the edge of the support so that the center of gravity (Fig. 71*a*, position I) is outside the support area. When the crane hook goes down (it is indicated by arrow *A*) the item starts rotating about the block rib and its edge will rest against the area surface (position II). If the center of gravity turns out to be beyond the point of support the item will take the vertical position by itself when the crane hook goes down further. If the center of gravity is to the left of the point of rest, the item is to be positioned vertically (position III) by moving the bridge or the trolley. To facilitate the tilting from position II to position III the item is to be reslung by the point *m*.

Tilting with a kick is the simplest method. It involves no jerks to the sling and to the crane but is applicable only in the case when the item to be turned over is massive and is not liable to deformation. While tilting with a kick the sling is attached to point *1* or point *2* (Fig. 71*b*, position I) enveloping the item. The crane hook moves up and lifts the item from the platform. Movement of the trolley (position II) or the bridge tips the item to its end face (position II) or (if necessary) to another side (position IV). The angle member is needed to prevent the item from turning over by inertia. The item can be hooked by the trunnions: if tilting onto the end face—by the left trunnions (Fig. 71*c*, positions I, II), if tilting onto another side—by the lower right-hand trunnions (position III). While tilting such items with a kick, keep in mind that size *B* must always be less than size *C*; otherwise, the slings and the crane ropes are subjected to heavy jerk and can even be broken. If size *B* turns out to be greater than size *C*, an adequate support is to be placed under the load before tilting (Fig. 71*c*, positions III and IV).

Items having no places for gripping and difficult to be tied up with a sling (disks, flanges, etc.) are turned over with a kick by means of a L-shaped tilter (Fig. 71*d*) upon which the item is placed with the aid of special tongs or other facilities. The hook going up, the arrangement together with the item is turned about and is thrown onto its opposite side.

Review Questions

1. What items can be tilted manually?
2. What is the way of items tilting by cranes?
3. What mechanisms are used for tilting?

7.2. Tilting Grounds and Accessories

Tilting grounds. To tilt loads by cranes, special grounds with shock-absorbing surface (tilting grounds) are organized. They are necessary to absorb shocks during fall of the loads being turned over and to prevent items from damage. It is poor practice to tilt loads on an ordinary wooden, brick, asphalt or other floor since the surface gets ruined and pot-holes are formed.

The type and size of tilting grounds are determined by the dimensions and weight of the load being turned over and also by the condition of the floor surface, density of equipment arrangement, the width of passages, availability of free area, etc. In workshops for machining and assembling heavy-weight and large-size components, the tilting grounds are organized right along the production lines not far from metal-cutting machine tools in places not dangerous in case of accidental fall of the load.

The construction of tilting grounds is not difficult, they can be organized in each workshop without great material expenses. A tilting ground shown in Fig. 72*a* is actually a wooden flooring made of boards 60-70 mm thick. The boards are interconnected by dogs. In some places the flooring is nailed to the floor. Such tilting grounds can be used for tilting parts with a concentrated weight up to 800 kg and frame parts weighing up to 3 tonnes. Tilting grounds of this type can be organized even in the passages between machine tools. To tilt component parts of an average size weighing up to 4-6 tonnes, filled-in grounds are used (Fig. 72*b*). They are edged with wooden bars 180 × 180 or 200 × 200 mm in cross section interconnected with dogs. In several places the frame is attached by rods to the floor. The shock-absorbing layer of fine broken stone is filled into a level 100-150 mm higher than the bar level. Being struck by the loads, the broken stone gradually gets finer and compact, therefore it should be supplemented as required so that it always reaches the bar level.

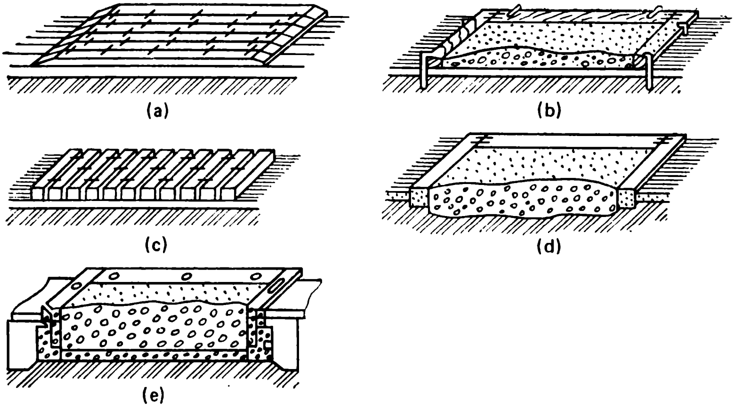

(a) (b) (c) (d) (e)

Fig. 72. Tilting grounds:
a—tilting ground made of boards; *b*—filled-in tilting ground; *c*—tilting ground made of logs; *d*—pit-filled tilting ground; *e*—tilting ground with a vibration damping belt

Items weighing 6-10 tonnes can be tilted on a ground made of logs 250-300 mm in cross section (Fig. 72*c*).

The bars are interconnected with dogs. A log flooring can be placed on any base.

A pit-filled tilting ground (Fig. 72*d*) is organized for tilting component parts weighing 50-100 tonnes. Its construction is similar to that of a filled-in ground. The shock-absorbing material is charged into a pit 500-600 mm deep whose walls are edged with wooden bars 200 × 200 mm in cross section. The bars must protrude above the floor level by 60-70 mm. The bars are interconnected with dogs. Granite or some other broken stone is filled in by 100-150 mm above the bar level, and new portions are added as required.

A tilting ground with a vibration damping belt (Fig. 72*e*) is used for turning over the items weighing more than 100 tonnes. The depth of the filled-in portion of the ground is 500-600 mm. The ground pit has a concrete foundation with a ferro-concrete parapet. The wooden bars framing the ground are secured with stay-bolts dead-held in the parapet foundation. The bolts are located at a distance of 1500-1600 mm from each other. A 200 × 200 mm bar emerges above the floor level by 60-70 mm. The pit is filled with broken stone. A broken stone vibration damping belt 500-600 mm wide is made around the ferro-concrete parapet to the depth somewhat lower than the pit bottom. The purpose of the trench is to damp vibrations caused by the impacts of the loads being turned over. The vibration damping belt is necessary if there is precise equipment or assembly line of precise machines in the vicinity of the tilting ground.

As a rule, tilting grounds have no fencing since practice has shown that the fencing interferes with the work and sometimes is the cause of people's injuries. The grounds are to be fenced from the most critical sides and thereby the fencing must be sufficiently strong to withstand accidental impacts of the items being tilted. All the tilting grounds should be 1-3 meters wider than the dimensions of the items being tilted and twice as long.

Tilting accessories. In addition to slings the tilting grounds must have one-two angle members, several supports and prisms differing in height, one-two beams for securing the angle members. Cast or welded supports (Fig. 73) are from 500 to 1500 mm in height. To facilitate their transportation and fabrication, they are made with holes. The support may be without holes but with trunnions for securing slings. They may be also box- or hollow-type. Box-type supports are made 200-1000 mm in size. A cast angle member serves as a support against which the component parts being tilted are leaned; its height is 2500 mm. A cast mounting beam is used for securing the angle member. On the ground it is grouted in concrete somewhat higher than the floor level. The upper

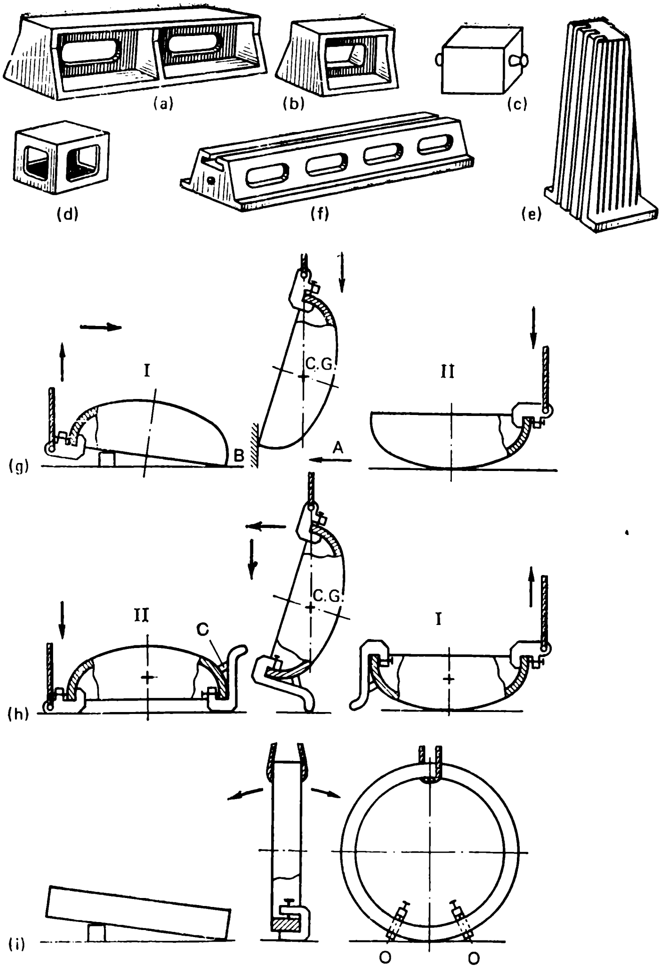


Fig. 73. Tilting accessories:
a and *b*—cast or welded supports; *c*—support with trunnions; *d*—box-type support; *e*—angle member; *f*—mounting beam; *g*—tilting by means of ordinary cramps; *h*—the same but by means of special cramps; *i*—the same but by means of locksmith's cramps

part of the beam is provided with a T-shaped groove to receive the bolts securing the angle member.

Tilting of vessel bottoms, big rings and bands whose outer diameter is up to 5 meters and the weight is up to 30 tonnes has a number of peculiar features which necessitate employment of additional tilting accessories. Figure 73*g* illustrates the process of tilting of bottom plates from position I to position II by means of lifting cramps. The design of this bottom plate is such that when the crane hook goes down the item can spontaneously slip away in the direction of arrow *A* causing jerks and break of the rope. To avoid this, use is made of stops (Fig. 73*g*, stop *B*) which may be various objects found nearby the place of tilting. To tilt bottom plates, in addition to general-purpose cramps and stops, use is also made of special lifting cramps forming additional supports (Fig. 73*h*). Welded to the support lever of the cramp is strip *C* to prevent the lever from bending. The bottom plates of a greater size are provided with two support arrangements to facilitate tilting.

When tilting rims, shrouds, and the like items whose diameter is greater than 2 meters on a hard floor or on a tilting ground with a very dense surface, the items tend to rotate about their vertical axis. To get rid of this undesirable phenomenon, two locksmith's or ordinary lifting cramps are secured to the item at point *O* (Fig. 73*i*) thus forming temporary supports.

Accessories are stored and employed in a manner similar to the rest of slinging and load-handling facilities.

Review Questions

1. What is the construction of a tilting ground?
2. What accessories should be available at a tilting ground?

7.3. Tilting of Materials in Metallurgical Practice

The technological process of metal making requies tilting of ladles for pouring iron into mixers.

Ladles are tilted by means of casting cranes provided with two hoisting mechanisms. In this case the slinger is to check the crane suspensions with hooks and the condition of the grippable accessories of the ladles. Having ascertained that they are in good order, he slings them. The tilting mechanism of the mixer operates automatically, i.e. independently of the slinger. The mixer is tilted in the direction of the runner by means of a tilting device. The mixer resumes its initial position under gravity since the rotation axis of the mixer is somewhat shifted from its center of gravity. Moulds are tilted by slings on special platforms. For this purpose, they are provided with two pairs of trunnions.

At blooming and slabbing mills a displaceable tilting mechanism is located at the manipulator head.

A tilting device for iron-carrying ladles is designed for tilting iron-carrying ladles when teeming molten iron at the casting machine stand.

Electric furnaces are provided with a tilting mechanism whose drive (hydraulic or mechanical) is designed for tilting the furnace through 40° in the direction of the casting bay in the process of metal tapping and through 12° in the direction of the charging door during the slag flushing. The mechanism has a travel limiter for both directions of tilting.

Provided in the furnace tilting mechanism are independent electric drives for each rack. Should one of the drives fail, the furnace can be tilted with the use of the other one at a reduced speed.

Review Questions

1. What are the peculiar features of tilting in metallurgical practice?
2. What is the construction of the rolling mill tilter?

· Chapter VIII

Transportation of Materials in Metallurgical Practice

8.1. Dangerous Zones

To accomplish technological operations, metallurgical practice employs various load-lifting cranes: gantry cranes, travelling electric cranes, including special metallurgical and jib cranes.

Gantry cranes can convey loads at a fairly great speed and do not require erection of expensive trestles. According to their construction, gantry cranes are divided into jib and jibless ones. Gib cranes have a span structure with jibs for moving the trolley over the columns which makes it possible to convey the loads beyond the span structure through the openings between the columns. Jibless clanes have no such possibility which simplifies the structure but makes the cranes less effective in load handling operations.

Overhead bridge cranes are the most widely spread type of cranes in ferrous metallurgy. They are different in their purpose, load capacity and design. A travelling electric crane comprises a crane bridge having a travelling mechanism, a trolley with a hoisting mechanism and control cab. The crane travels along the workshop or work site over crane tracks. Depending on the crane purpose the hoisting mechanism is provided with various lifting attachments: hook, load beams, tongs, mechanical grips, electromagnet or clamshell. As distinct from a hook crane, the clamshell crane trolley carries alongside with a travelling mechanism two similar mechanisms: one for lifting the clamshell and the other for its locking.

To carry out auxiliary technological operations (movement of ferroalloys, stoppers, etc.) and repairs, cantilever cranes are widely used. They show better manoeuvrability since they have their own crane tracks which are independent of the main technological cranes.

In coke and agglomeration industries, coal and raw-ore stockyards gantry and bridge cranes are used for unloading ore and coal from freight cars, for charging them into freight cars and receiving bunkers, for moving coal and ore from pile to pile with the aim to average the charge composition. People are usually kept away from the operating zone of gantry cranes. Safety of the crane operator, repair personnel servicing the crane is to be provided. Repairs are usually carried out under adverse conditions (outdoors) and very often not using any means of mechanization. Therefore, the safety of the personnel servicing the crane depends on a competent operation of the crane and proper organization of repairs.

Gantry cranes are provided with the following means of signalling, instruments and safety devices: limit switches of the crane travelling mechanisms, trolley, hoisting attachment; interlocking of cab doors to prevent the crane from moving with the door open; automatic skewness limiter to prevent the crane from tipping; antiskid devices; horn.

In open-hearth and electric steel making shops many technological operations are carried out by means of cranes. *Mixer cranes* are used to transfer iron from iron-carrying ladles to mixers. In charge bays the scrap and bulk materials are loaded by *magnetic* and *clamshell cranes.* In the furnace bay *hot-metal cranes* are used to pour molten iron into a steel making furnace, to move fettling machines, bins for filling sills, iron guiding runners. In pouring bays the cranes lift ladles with steel, change slag bowls and carry out a number of other auxiliary technological operations. Practically, the entire shop area is within the reach of different cranes. Moreover, in the operating zone of cranes various equipment is located: charging machines, locomotives moving charging box trains with scrap and bulk materials, trains with hot-metal ladles, moulds for steel teeming. Crane operation in steelmaking workshops calls for necessity to provide safety to both crane operator and maintenance personnel and process workers operating within the crane zone.

Special metallurgical cranes are provided with the following safety means: overhoist safeguard and limiters of crane travel; fencing of work sites, moving and rotating members of cranes, current-conducting elements; interlocks of cab doors and doors leading to the crane bridge; horn. To insure safety of steelmaking shop workers, proper organizational and technical measures are to be developed which prescribe the operation procedure of the workshop equipment.

In ingot stripping bays *special stripping cranes* are used to withdraw ingots from moulds, to remove tops and the like operations. They operate under the conditions of high heat radiation from hot metal, high temperatures and dusty atmosphere. Working within the reach of the stripping crane are the workmen of this bay and of railway workshops who accompany the trains with moulds and maintenance personnel servicing mechanisms located in this area. This calls for high qualification of the personnel servicing the machines who must have profound knowledge of the design and safe operation rules of load lifting machines. Stripping cranes are provided with the following safety devices: crane and trolley travel safeguards; ingot hoisting limit switches; fencing of operating grounds, moving and rotating parts of the crane, and current-conducting elements; interlocks of cab door and doors leading to the crane bridge; horn.

In mill workshops *special dogging cranes* are engaged in such operations as charging ingots into reheating pits, drawing ingots and loading them onto an ingot car. They operate under adverse conditions of high temperatures and heat radiation. Working in the crane zone and area for servicing heating furnaces are process personnel and on the ground level are workmen of the railway workshop.

In rolling-mill shops metal is moved by special *rolled stock cranes*. These are bridge cranes with claws on a load beam. They are used to move, stack in piles and load rolled stock. At the finished product storage areas they load finished rolled stock into freight cars. Permanently working in the zone of crane operation on the adjustage are operating personnel engaged in conditioning the surface, loading metal to freight cars, process and maintenance personnel servicing the equipment. The safety of operators working in rolling-mill shops greatly depends on the competent operation of the cranes. Rolled stock cranes are provided with special attachments for gripping metal which prevent it from falling down during movement, and also with load overhoist safeguards, crane and trolley travel safeguards, limit switches, fencing of operating areas, moving and rotating parts of the crane, interlocks of the cab door, and a horn.

In addition to special metallurgical cranes sited there is a great number of general-purpose overhead bridge cranes of different capacity in the main and auxiliary shops. These cranes help to carry out many auxiliary operations in cleaning production areas, repairing equipment, etc. There are many people working in the operating zones of these cranes. To move loads by the general-purpose cranes, usually two persons are engaged: a crane operator and a crane attending worker; they are responsible for safe operation of the crane.

The main causes of accidents are violation of safety rules by crane operators and crane attending workers; poor maintenance of the equipment; absence, failure and ignorance of safety instruments and devices.

The most frequent violations of safety rules are movement of loads over people; loading and unloading of materials into freight cars while slingers are present in the cars; lifting of loads when a slinger is in the dangerous zone, etc.

Review Questions

1. What cranes are used in ferrous metallurgy?
2. What operations in metallurgy are carried out by special cranes?
3. What are the main causes for accidents in operating a crane?

8.2. Load Transportation by Two Cranes

To transport very heavy loads and sometimes to pour hot metal, two cranes have to be used (Fig. 74*a*).

Tandem transportation is a demanding operation. Therefore, it is allowed to be carried out only under a direct supervision of a person responsible for trouble-free operation of the cranes and work safety. Tandem hoisting and transportation by two cranes is possible provided that the following conditions are met: absolute serviceability of both cranes and synchronism in operation of the brakes; equality of crane mechanism speeds and load exerted on each crane; horizontal position of the load being transported which is achieved by using slings of equal length; vertical position of taut load ropes.

If the load is being hoisted with a lifting beam its capacity must correspond to the weight of the load. If the cranes are of equal capacity the load beam must have equal arms (Fig. 74*b*), i.e. the load carrying hook is to be in the middle of the beam. If the cranes are of different capacity the beam is made with different arms. In this

Table 13. Characteristics of Cranes

Lifting capacity, tonnes			Dimensions, mm			
Q_1	Q_2	Q_1+Q_2	Crane width, *B*	Minimum permissible distance between hooks of cranes, *A*	L_1	L_2
15	15	30	6300	7000	3500	3500
15	20	35	6300	7000	4000	3000
20	20	40	6300	7000	3500	3500
20	30	50	6300	7000	4200	2800
30	30	60	6300	7000	3500	3500
30	50	80	6300	7000	4400	2600
50	50	100	6300	7000	3500	3500
50	75	125	7450	8200	4900	3500
75	75	150	8800	9600	4800	4800
75	100	175	8800	9600	5500	4100
100	100	200	8800	9600	4800	4800
100	125	225	8800	9600	5300	4300

Note. Total lifting capacity must be 10% greater than the total weight of the load being lifted and the beam.

case the load hook is located on the beam so that the distance from the hook to the shackles (crane hooks) (Fig. 74*c*) is inversely proportional to the crane lifting capacity $L_1/L_2 = Q_2/Q_1$, where L_1 and L_2 are the distance from the hook to the beam shackles; Q_1 and Q_2 are the lifting capacity of the cranes.

Consequently, the short arm of the beam should be closer to the crane of greater capacity, whereas the long arm, to the crane of smaller capacity. When using a different-arm load beam for tandem lifting, the load applied to each crane is checked by the formulae $Q_1 = PL_2/A$ and $Q_2 = PL_1/A$, where P is the total weight of the load being lifted and the beam; A is the distance

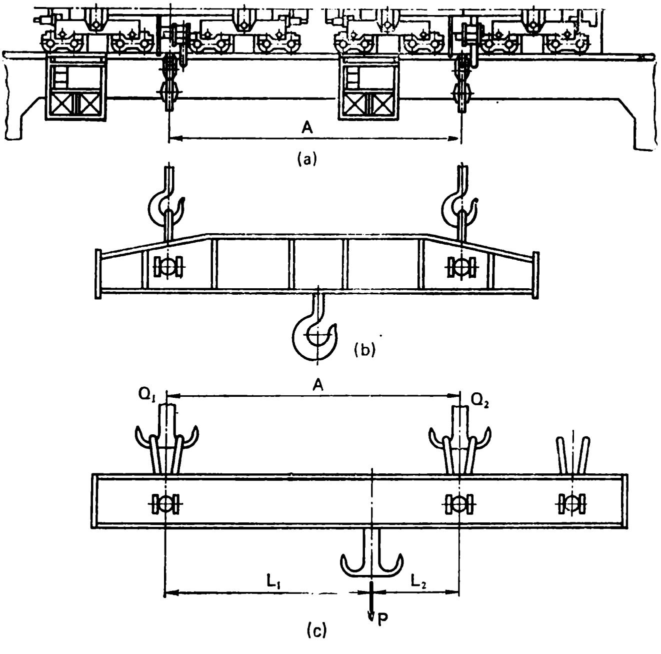
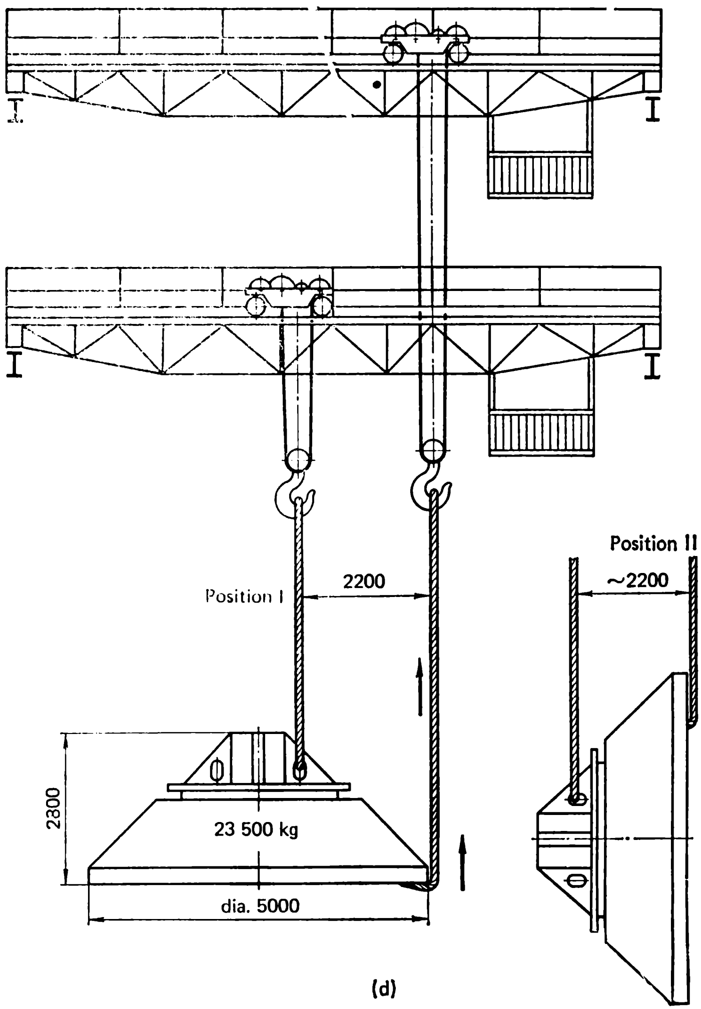


Fig. 74. Load transportation by two cranes:
a—bridge cranes; *b*—equal-arm load beam; *c*—different-arm load beam; *d*—sequence of tilting (I and II—positions of the item in the course of tilting)



(d)

between the beam shackles, i.e. the distance between the crane hooks suspended vertically.

Table 13 indicates the distances between the crane hooks and beam shackles for tandem operation in cases most frequently used.

For cranes with a single hook the attaching stirrups of the beam are made also single (Fig. 74*b*), whereas for cranes with a sister hook the double stirrups are used (Fig. 74*c*). It is prohibited to suspend the load beams with single stirrups from sister hooks, and vice versa the beams with double loops are prohibited to be suspended from single hooks. Long items such as shafts, press columns, etc. whose length is more than 7-9 meters can be transported without any beams.

In shops with a high ceiling sometimes the loads have to be transported and tilted by two cranes which are located one above the other, i.e. on two levels. For example, at the Urals Machine-building Plant it was necessary to take the great cone of the blast furnace by two cranes from an intershop transport car where it was in the horizontal position (Fig. 74*d*, position I) and place it in the vertical position onto a great capacity flat car (Fig. 74*d*, position II), since the item diameter was beyond the railway loading gauge. The item could not be moved to the tilting ground therefore it was decided to move and tilt the item by two cranes located at different levels. First the item was somewhat lifted and inclined by the lower level crane, then it was pulled up to the vertical position by the upper level crane whose hook was passed through the lower crane truss. In such a position the item was moved and placed onto the flat car. Thus, two cranes allowed to carry out two operations at a time: tilting of the item and its transfer from one car to another one.

However, such operations are possible to be carried out by two cranes located one above the other under the condition when the trolleys of the lower level crane are located outside and the ropes of the upper level crane do not come in contact with the lower level crane trusses.

The person responsible for hoisting the loads by two cranes should acquaint the crane operators and slingers with the weight of the item to be lifted, with the place to which the item is to be transported and placed, with the signals sent to the crane operators. During hoisting he must stand in such a place from where the load being lifted and signals being given are well seen.

Unauthorized personnel are strictly prohibited to pass and perform any work within the dangerous zone. It is strictly prohibited to remove limit switches and travelling mechanism safeguards.

If during the lifting or movement of the load the crane operator notices any fault in any mechanism or brake, he is to give a sound signal (three strikes) and then the person responsible for crane operation is to give the signal "Stop" to discontinue all the work until the defect of the crane is removed.

Review Questions

1. What are the cases when the load is lifted by two cranes?
2. What is the method of distribution of the load among cranes when the load is lifted by two cranes of different lifting capacity?
3. What conditions are to be observed when the load is lifted by two cranes?

8.3. Movement of Materials to Melting Furnaces

Movement of charge materials, additives, deoxidizers and fettling materials in all the shops is mechanized. Pan cars are equipped with devices for automatic and semi-automatic coupling which make it unnecessary for the workers to be present between the cars during coupling and uncoupling of pan-car trains and with stops or lugs preventing the charger pans from displacing in the longitudinal direction during jerks and shakes. In a car-ahead movement a train, as a rule, is accompanied by a locomotive driver's assistant.

While moving pan-car trains to the furnace bay from the hot-metal track to the furnaces the charging foreman should stand on the way of the charging machine and the locomotive driver's assistant should stand in the place from where the locomotive driver and the foreman are seen. In all the cases when the driver does not see his assistant he must immediately stop the train. In case of a locomotive-ahead movement of the train from the stockyard to the work ground, the driver is to give frequent signals and the driver's assistant is to accompany the train moving ahead of the locomotive between the tracks on the driver's side. Stockyard foreman, charge mixer and charging foreman having a qualification of a slinger are allowed to replace a faulty pan car by means of a crane.

In all the cases of repairing the trains portable stop signals must be installed at a distance not less than 15 m from the train under repair.

Hot iron is delivered to the shop in hot-metal ladles provided with automatic couplers. It is prohibited to ride the carriages of hot-metal ladles and to uncouple them on the move. At the moment of delivery of hot metal to the surface area the workmen on the way of movement are to be removed to the safe place.

Ladles with hot metal are allowed to be moved along the shop only in those shops where there are no railway tracks along the furnace front.

Ferroalloys are delivered to shops in charger pans, containers or in self-discharging bins. Prepared ferroalloys are stored in special bins located between the furnaces. Unloading of ferroalloys into the bins and their delivery to the furnaces are mechanized.

Electric melting furnaces are loaded from the top by means of a special bucket. Before charging the bucket it should be thoroughly inspected. While inspecting one should consider the condition of the bucket segments, their attachment, serviceability of the lock for clamping the rope, the condition of chains, their attachment to the load beam and to the seat. Moreover, the condition of the bucket, lock and chains is checked after each loading of the furnace.

It is prohibited to convey the bucket for loading if its segments are broken.

Before loading the charge into the bucket its bottom is to be covered with a layer of metal sheet cuttings to prevent the lock and the line from damage. The charge maker checking the filling-in of the charging buckets must stand in a safe place. While loading the bucket it is necessary to inspect all the hollow bodies. If there are objects unfamiliar to the charge maker they are to be put aside for further inspection by pyrotechnicians.

Used for climbing the bucket top and for descending from the bucket are light-weight portable metal ladders with hooks by which the ladders are secured to the bucket side. While performing any work inside the bucket one operator is to be present outside. While rolling the bucket out of the furnace bay or back the charge maker is to make sure that there are no people on the way and the entrance is not barred with charge. Between the extreme protruding portions of the car and elements of the structure, equipment and the materials being stored there should be a space not less than 700 mm on both sides of the car. The starting mechanism of the car for transporting the charging bucket should be designed so that it excludes an undue beginning of its movement. It is prohibited to lift the charging bucket to the working platform of the furnace without a seat (pallet). A special load beam is used for transporting the charging bucket by a crane. A sound signal is given to indicate the coming bucket lift to the working platform and during charging of the burden into the furnace.

After the burden has been charged into the furnace, the crane lowers the bucket to a required height from the floor for inspection. During inspection the charge maker must personally make sure that there are no slag pieces on the bucket and on its segments. Materials being charged into electric furnaces are preliminarily dried and calcinated. It is prohibited to feed wet materials into a molten bath.

To move buckets, pans and scoops in converter process self-propelled cars (scrap cars) are used. The cars are provided with two control consoles. While moving, the cars give sound signals. The cars for moving scoops are provided with reliable brakes and stops preventing the scoops from slipping off the cars.

A scrap car is powered by two similar propelling mechanisms which operate simultaneously. Should one mechanism fail, the second one insures normal run of the scrap car until the operation is over. Attached to the scrap car end beams are special hooks designed to withdraw it from the converter bay in case of emergency or failure of both propelling mechanisms. For this in view, provision is made for a special winch with a 5-tonne traction force.

All the mechanisms engaged in delivery and charging of bulk materials into the converter are remotely controlled.

Hot metal is delivered to converters in ladles moved by electric cars, diesel or electric locomotives. Each converter shop must have a safe parking zone for locomotives during hot metal pouring into the converter.

Storing places of blanks and ingots are equipped with stock cranes, roller beds, transfer beds and pushers.

The cranes usually have magnets and mechanical grabs (claws) to prevent the load from falling in case of their break from the electromagnet.

A roller bed (a roller conveyor) is a device to convey mass production and unit items over rollers frequently spaced on a support frame. Roller beds may have live-roller driven table or dead roller table. On the dead roller tables the loads are moved manually or they slide over inclined surface by the force of gravity, while the rollers of live tables are rotatable by means of a special drive. Dead roller tables are used in storage places whereas live-roller ones are employed in rolling-mill shops. A transfer bed is a mechanism used in rolling mills, in storage places for transverse movement of the metal being rolled; it comprises a rod, a grip and a special drive. Pushers and trippers are designed to unload conveyors and receiving devices.

Blanks in the storage places are to be stacked in regular piles. The ground under the piles must be strictly horizontal. Aisles not less than 1 m wide are to be left between the pile rows. A permissible height of the piles in accordance with the size of blanks and ingots, methods of stacking and loading is given below, m:

	Method of loading
Large ingots for blooming mills	4.0/2.0
Small ingots, blooms and short-cut billets	2.5/1.5
Long-cut billets (>4-5 m)	4.0/2.5
Wide sheets	3.0/2.0
Slabs, the length of which in m is:	
$\leqslant 1$	2.5/1.5
>1	4.0/2.0

Note. The numerator denotes a mechanized method of loading, whereas the denominator indicates the non-mechanized method of loading.

Before inspection and conditioning, ingots and billets are cooled to a temperature below 50 °C. Thereby tilting of billets and ingots must be mechanized. While removing flaws from billets and ingots by a flame method, the gas-feeding hoses should be inspected. They must be intact to prevent gas leakage. Oxygen is fed to the station of flame conditioning of billets in a centralized way via pipe lines from a central oxygen station or oxygen header. It is prohibited to deliver oxygen to the places of flame conditioning in flasks.

Review Questions

1. What are the rules of materials delivery to open-hearth furnaces?
2. How are materials charged into an electric melting furnace?
3. How are materials fed to a container?
4. What are the rules of billets stacking?

8.4. Gesture Signals Used in Materials Handling by Cranes

Any enterprise must have a strict procedure of signal exchange between the slinger and crane operator (driver) recommended by Higher Inspection Agency (Table 14).

Table 14

Action to be performed	Figure	Gesture signal
Hoist the load or the hook	Fig. 1	Intermittent upward movement of hand in front of the chest, the palm is up; the arm is bent in the elbow
Lower the load or the hook	Fig. 2	Intermittent downward movement of hand in front of the chest, the palm is down; the arm is bent in the elbow
Move the crane (bridge)	Fig. 3	Movement of extended hand, the palm indicating the direction of the required travel of the crane (bridge)
Move the crane trolley	Fig. 4	Movement of arm bent in the elbow, the palm indicating the required direction of the crane trolley movement
Slew the crane jib	Fig. 5	Movement of arm bent in the elbow, the palm indicating the direction of the required movement
Lift the jib	Fig. 6	Upward movement of extended arm from vertical position, the palm is open
Lower the jib	Fig. 7	Downward movement of extended arm from vertical position, the palm is open
Stop (stop hoisting or moving)	Fig. 8	Sharp movement of the hand to the right and to the left on a waist level, the palm facing down
Be careful (the signal is given before any of the above-described signals and when the required movement is inconsiderable)	Fig. 9	The palms face each other at a close distance, the hands being raised up

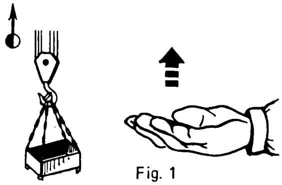


Fig. 1

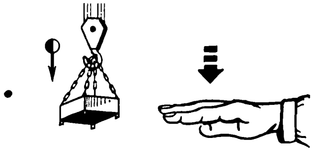
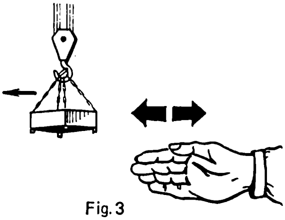


Fig. 2



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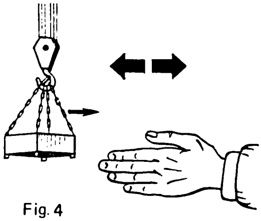

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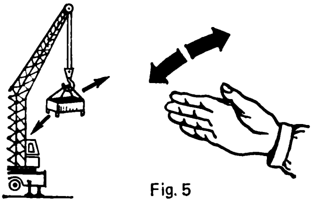

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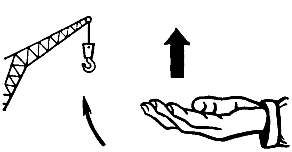

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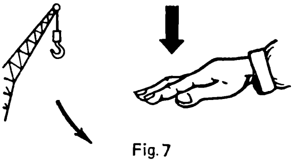

Fig. 7

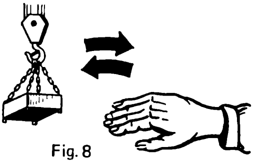

Fig. 8

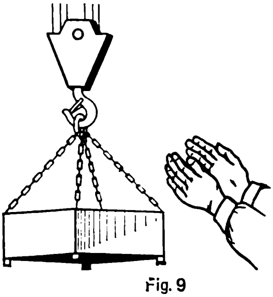

Fig. 9

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Chapter IX

Safety in Slinging Operations

Safe operation of load handling machines and mechanisms is provided by observing the Safety Code by crane operators and slingers, by improving the skills of the personnel servicing these machines, by correct maintenance of the equipment and by competent slinging of the load.

Organization of safe work of a slinger. Peculiarities of work at metallurgical plants make it necessary for the entire operating and maintenance personnel to work as slingers. In this connection the personnel of shops must undergo a course of theoretical and practical training in slinging operations according to a special curriculum, probation training at the work site of slingers and pass examinations to the enterprise commission. Workmen who have successfully passed the examinations are awarded a special certificate and are granted a permit to work. The holders of these certificates must know the general construction of a crane, an adopted procedure of signals exchange with the crane operator, methods of loads slinging, rules of item stacking, construction and handling of packages, tolerance limits for steel ropes and welded chain slings, conditions and procedure of load lifting and transportation by two cranes, know how to sling loads and correctly suspend loads and load lifting attachments from the crane hook, assess the weight and location of the center of gravity of the load, determine fitness for work of load handling attachments and packages, etc.

Before starting the work the personnel who is acting as slingers, gets assignment from the supervisor for the work to be done during the shift, inquires of the crane operator about the conditions of the load lifting machine, surveys the work site paying special attention to the illuminance and condition of the storage places, checks the availability of special spacers, chooses necessary load handling attachments and packages corresponding to the weight and type of the load to be hoisted. If the required load-handling attachment is not available, there is no tag or a mark thereupon, or the crane is out of order, the load lifting operations are postponed.

Before starting the work the slinger must assess the weight of the load to be lifted and transported since the overload may result in breakage and injuries. The slinger must work with his mittens on.

Modern metallurgical cranes have a number of independently operating hoisting mechanisms, but only one is allowed to be used. Before starting to lift the load the slinger must demand from the crane operator that the inoperative mechanism should be disengaged from the lifting attachments and hoisted to the upper position. The loads are tied and hooked in accordance with the slinging procedures developed at this plant.

Before transportation the piles of shaped and sheet metal are tied with special tape or annealed steel wire. While slinging tubes and other hollow items it is necessary to remove all the objects from the hollow spaces which can fall out during transportation, and to make sure that the load to be lifted is not attached, not gripped, not heaped up, not welded or not frozen to the ground. While slinging the load the slinger is not allowed to use slings which are not prescribed for the given slinging operation, to hang the load from one nose of a sister hook, to use slings whose legs are spread by more than 90° during slinging. Before hoisting the load the slinger must ask all the people to leave the crane operating zone and to make sure that the work execution is safe.

The load movement over the floor under which production or service rooms are accommodated where people may be present, is carried out with additional precautions: posters are displayed, fencing is set up, signal systems are organized, warning signs are posted to inform about the load movement or to keep people from moving within the crane operating zone.

While removing equipment from the foundation the slinger is obliged to observe the following safety rules: he must make sure that the equipment to be removed is deenergized, that the foundation bolt nuts are screwed off and withdrawn; he must find out whether the equipment is broken from the foundation by means of wedges or a lifting jack; he must keep watch on the lifting which should be smooth without any skews or jamming at the foundation bolts. Long loads are lifted with the use of hemp guy ropes through which the load can be held against rotation. In the horizontal direction the load is moved at a height of not more than 0.5 m from the objects encountered on its way; thereby the slinger must accompany the load by walking behind it. The slinger may not accompany the load if the crane operating zone is fenced, posters are displayed which prohibit people from entering this zone and there are no people in the zone except the slinger. Two slingers are engaged in the operation: one of them hooks the load and the other relieves the load from the handling attachment; both slingers must see the load along the entire path of its movement.

Before lowering the load down the slinger checks the availability of spacers of an adequate strength under the load being placed, and absence of people in the dangerous zone.

It should be a must that the slinger gives a signal to the crane operator to hoist the released or loaded hook only after he has withdrawn his hands from the slings or hooks.

Loads are positioned by means of special grapples not less than 1.5 m long. In carrying out maintenance operations involving precise positioning of the equipment, metal structures, or items, it is allowed to turn and guide the load by hand. In this case the load may be held by hand only when it is not higher than 100 mm above the place of installation. The load is placed onto the floors observing the following dimensions: the distance from the railhead of the track to the load or to the pile up to 1.2 m high should be not less than 2 m and if the pile is higher, not less than 2.5 m; the distance from the protruding parts of the rolling stock of the narrow-gauge rail track and from the outer parts of transfer cars to the pile or to the load should be not less than 1 m; the distance from the equipment to the pile or to the load should be not less than 0.7 m; the passages between the piles should be not less than 1 m in a transverse direction and not less than 2 meters in a longitudinal direction, the drive ways between the piles must be equal to the vehicle width plus 1 meter on each side; the height of the pile stacked with participation of a slinger should be not more than 2 meters, of those stacked without slinger's participation, not more than 4 meters.

In all the cases irrespective of the degree of mechanization of the load piling process the height of the piles should not exceed the width of the pile.

Work safety of slinger servicing casting cranes. Any operations performed by means of casting cranes (pouring of hot metal into mixers, converters, open-hearth furnaces, transfer of steel from ladle to ladle, teeming of steel into moulds) are allowed only after all people are removed from the dangerous zone of crane operation. The slingers servicing these cranes (mixer operators, steel makers and their assistants, senior cupola attendants, casting operators) have additional responsibility to examine load-handling attachments before their hooking. Prior to putting a casting crane into operation the slinger should inspect the attachments, ladles, bowels and make sure that there are no cracks and deformation in the laminated and forged hooks and shackles and in the metal structures of the main load beams and in the beams for ladles and bowels. He must inspect the reliable attachment of axles of laminated hooks and beams, forged hooks, axles of the sheaves and balance beams of ropes; he should make sure that sheave flanges are not damaged and the sheaves rotate easily, that there are no cracks and deformation in trunnions and ears of the ladles and slag bowels, that the ladles and bowels are in good repair and that there is no slag, scrap and moisture in them.

While transporting hot metal and slag the slinger is to keep watch on the metal level in the casting (hot-metal) ladles and slag bowel. Before transporting a ladle he must demand from the crane operator that the hoisting mechanism brakes should be checked for proper functioning. The crane operator lifts the ladle to a height of 300 mm from the support surface of the stand (carriage) and checks the brakes for proper operation.

Before tilting the slinger must see that the ladle ear is correctly and reliably engaged with the auxiliary lifting hook.

The casting cranes are prohibited to be used for transporting hot metal ladles along the spans, moving trains of hot metal ladles and slag cars; steel teeming on the teeming grounds in front of the steel making furnace under repair; recovering the steel teeming trains which have been caught by spilled hot metal without preliminary undercutting of sluggish metal with oxygen.

Safety work of slinger servicing magnet and clamshell cranes. No people are allowed in the working zone of magnetic and clamshell cranes. Slingers servicing these cranes are allowed to the operating zones of cranes (to clean the trains, to couple and uncouple the trains) only during the breaks in the crane operation after the magnet or clamshell is lowered onto the ground. If the production needs require the presence of people in the crane operating zone who are engaged in continuous production processes (charge makers in steelmaking shops, cutting torch operators in scrapbreaker shops, scarfers in rolling mill shops), additional safety measures are taken: light warning panels and posters are displayed at the entrances and drive ways of the shop which prohibit unauthorized personnel to enter and drive in the shop; fixed and movable fencings are erected; warning posters which limit the area of handling operations are displayed; safe passages having protective coverings are made; routes of safe transportation of materials are traced. Before putting a magnet crane into operation the slinger checks the condition of the load handling attachment for securing the electromagnet to the hook or beam of the crane; availability of electromagnet marking, capacity and its own weight; condition of the sheathing of the flexible cable supplying the electromagnet; serviceability of the electromagnet (by trial lifting of the load). Before putting the clamshell crane into operation the slinger inspecting the clamshell checks the condition of the clamshell scoops, pivotal joints, connecting links, the availability of a tag on the clamshell, its number, type of material for which it is designed, lifting capacity and its own weight; tightness of scoop closing (by a trial lifting of the load).

During operation of the clamshell or magnet crane the crane operator keeps an eye on the path of the crane and on the portion of the dangerous zone where people may come into view. While loading scrap into buckets, charging boxes and containers the electromagnet is switched off at a height of not more than 0.5 m from their bottoms.

Magnet and clamshell cranes are prohibited to be used to load materials into moving railroad cars; to start material handling operations until the locomotive is uncoupled from the train and brake blocks are put under the car wheels; to move empty containers with the electromagnet lowered into it; to transport equipment and people; to carry out operations for which these cranes are not intended; to move scrap pieces measuring more than 200 × 200 mm as well as molten and red-hot slag.

The work of a magnet or clamshell crane is over, the slinger lowers the electromagnet or clamshell onto a place specially prepared for it, disconnects the cable from the electromagnet or suspended motor-driven clamshell (if the cable is connected by means of a plug) and releases the crane hook from the lifting attachment.

Safe work of slinger servicing stock handling crane. Before putting a stock handling crane into operation the slinger checks the condition of grapples and the reliability of their attachment to the beams, the condition of chain slings holding electromagnets and the reliability of their attachment to the beams and to the electromagnets; fences the operation zone of the crane with portable warning signs and demands that people leave the dangerous zone. While transporting loads the slinger makes sure that the grapples do not approach the billets closer than 100 mm.

The load is allowed to be transported if the grabs brought under the magnet do not cover all the billets or the billets are located asymmetrically with reference to the pit axis. The metal is prohibited to be placed upon the cutting benches if they are not cleaned of the metal cuts and scale.

When stacking a pile the slinger must stand in a safety zone bearing in mind that the billet pile may roll off.

Review Questions

1. What should a slinger having a permit for independent work know?
2. What safety rules are to be observed by a slinger servicing casting cranes?
3. What safety rules should be observed by a slinger attending an electromagnet or clamshell crane?
4. What must a slinger attending a stock handling crane do to insure safe work?

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